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DEPTH PROFILES AND BULK ANALYSIS OF SEMICONDUCTOR MATERIALS USING ICP MASS SPECTROSCOPY WITH ELECTROTHERMAL ATOMIZATION

GeoChemical Services, Inc.

William Faulkner, William Henderson and Michael Rogers

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ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
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The purpose of the contract was to build the equipment necessary to show technical feasibility of a Demand Modulated Electrothermal Atomization System. This system was thought to have advantages over current technology as follows:

1. Prevents excessive analyte concentrations in the plasma giving the analyst control over matrix suppression effects.
2. Allows the analyst to control atomization rates and avoid buildup of deposits in the throat of the sample cone opening.
3. Allows the analyst to work in the optimum counting range for isotopic ratio work regardless of concentration variations.
4. Allows the data to be taken over the temperature dimension, thus resolving isobaric interferences as well as improving the signal to noise ratio resulting in improved detection limits across the entire mass range.

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5. Allows the routine use of high dissolved solids (>10%) as well as solid sample introduction.
6. Allows the routine use of small sample sizes - 100 ugms or less.

PERFORMANCE AGAINST PHASE ONE TECHNICAL OBJECTIVES:

Item #1. Software was created to collect and analyze data in three dimensions-AMU, concentration and atomization temperature. This software gives the analyst program control over a comprehensive list of variables. These are as follows:

1. Channels per sweep and dwell time.
2. Default maximum sweeps per summation buffer.
3. Default minimum sweeps per temperature step.
4. Default maximum sweeps per temperature step.
5. Default number of pulses per temperature step.
6. Maximum temperature increments before shutoff.
7. Number of initial sweeps to throw away.
8. Starting and ending temperature.
9. Number of sweeps per temperature increment.
10. Size of temperature increments.
11. Number of sweeps to be stored in each data histogram.
12. Starting and ending amu for scans.
13. Starting and ending amu for threshold control.

See software manual for detailed description.

Item #2. Atomization conditions for direct solid sample introduction were not accomplished due to the complexity and time constraints of the contract. Solid samples were introduced into the plasma under stable conditions and data was taken. Detailed methods development will be needed to determine valid parameters for specific analyses.

Item #3. Solid samples were not analyzed per se, however, analysis of 10% dissolved solids was accomplished. These results were presented at the 1987 Pacific Conference on Chemistry and Spectroscopy in Irvine, California.

Isobaric Interferences were temperature resolved for Cd and Pd at amu 106 and Hg and Pb at amu 204.

Item #4. VG Isotopes was not able to get the instrument to perform as specified. The background was high and the responses were low resulting in detection limit performance for the standard instrument that was three orders of magnitude high. For this reason, no detection limit studies were performed.

Item #5. The software and hardware were designed to accommodate computer control of various gases during an analysis. Specific studies were not accomplished because the instrument in use for this program had limited usable count rates of two million per second. VG's updated design (electronic) will now give up to ten million counts per second.

Item #6. Time did not allow this item to be completed.

Although some of the planned items did not get accomplished, the equipment and software built under this contract has demonstrated the ability to perform these tasks with additional work on specific methods for each type of analysis.

TABLE OF CONTENTS

INTRODUCTION

The goal of this contract was to refine GSI's concept of applying feedback control to an electrothermal sample introduction system as applied to a commercially available mass spectrometer manufactured by VG Isotopes The potential applications of this technology would be

1 The bulk trace element analysis of semiconductor materials such as silicon and gallium arsenide

2. The bulk analysis of other materials such as acids, solvents, dopants and source materials

3 The ability to do semiconductor device depth profiles.

The unique features of this concept are

1 Increased sensitivity

2 Resolving concentrations over a third dimension, temperature, eliminates interferences

3 Analysis of high dissolved solids(>10%)

4 Solid sample introduction.

5 Sample to sample memory decay typically exceeds six orders of magnitude

6 Prior knowledge of elemental concentrations is not mandatory

The results presented in this report tests the feasibility of these concepts

EXECUTIVF SUMMARY

Purpose

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6. Allows the routine use of small sample sizes- 100 ugms or less.

Performance Against Phase One Technical Objectives

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Summary of Completed Work

1. Designed and built a torch/furnace assembly that significantly reduced memory and allows the analysis of high dissolved solid and solid samples.

2. Designed and built a computer controlled power supply to provide the power to heat the furnace.

3. Designed and built the data acquisition board to acquire count data over amu and temperature in any form desired under computer program control.

4. Completed the software needed to control the data acquisition

and data analysis under complete control and definition by the analyst

5 Performed analysis demonstrating that all items worked as designed Data was taken resolving isobaric interferences with temperature as well as the introduction of high dissolved solids and solid samples

6 Two patents were applied for based on the concepts outlined for this contract using specific hardware developed under this contract A copy of these patents is provided in the addendum

Additional work needs to be done to develop method for the analysis of materials of interest This contract has provided all the hardware and software to accomplish this

Work has continued since the end of this contract to refine both the hardware and software for additional capability PLease see the addendum for a summary of this progress

Problems with Standard VG Plasmaquad as Delivered

Plasma/Vacuum Interface

Purpose

The interface is designed to allow as much atmospheric pressure plasma plus analyte into the high vacuum chamber containing the quadrapole and detector as possible

Problems

The holes in the cones which provide the entrance to the vacuum chamber must be kept very small, of the order of 1 mm During the analysis both the hole diameter and the surface roughness of the hole interior must remain constant This does not happen when analyzing many materials including samples containing total dissolved solids above 1% or strong acids

Discussion

Conventionally, if samples containing high analyte concentration were analyzed, the cone orifice would quickly become clogged and degrade the signal in several ways The hot analyte ions and atoms (up to 8000 deg K) strike the cold cone surface by traveling through the boundary layer flow adjacent to the cone with some sticking to it Others will sputter material away For low analyte concentrations, experience shows that an equilibrium is reached where very little material is either stuck to the cone or sputtered off

At high analyte concentrations more and more material sticks to the cone creating a disequilibrium that will clog the cone During this process two things are occurring simultaneously First, the cone orifice is getting smaller causing the signal to degrade because less analyte is getting through the orifice per unit time. Secondly, the clogging process makes the hole surface much rougher This in turn induces more turbulence in the plasma flow through the hole and hence a thicker boundary layer The thicker boundary layer produces more boundary layer mixing with the main plasma flow that further slows the velocity through the orifice With this slowing the signal is degraded by still less analyte flowing into the vacuum chamber as well as the increased generation of polyatomic species adding noise to the background

The GSI ETVS (Electrothermal Vaporization System) solves these problems by controlling the rate at which the analyte is introduced at the plasma/vacuum interface and by using a much smaller amount of sample needed (10-100 uL)

Detector Preamp Issues

Problems

The detector is not linear and not precisely reproducible in its response to the varying ion fluxes The pulse width of the preamp (45ns) causes "pulse pileup" or the overlapping of pulses to form longer pulse with the accompanying loss of data

Discussion

The detector is a continuous dynode type in which a continuous active surface is biased from one end to the other An impact causes an electron cascade to avalanche from one end to the other The bias current is less than 20 uA If the ion flux striking the active surface causes a cascade current of more than about 10% of the bias current, the bias current cannot replenish the active surface adequately Thus, later arriving ions do not produce a cascade large enough to trigger a preamplifier response until the surface of the detector has been replenished This leads to what is called detector fatiguing or loss of signal due to the inability of the detector to respond adequately This affect begins at about 2 million counts per second

Pulse pileup occurs whenever the incoming pulses from the detector to the preamp are spaced closer than 45 ns It is not dependent on the overall rate of ion influx, but on the immediate rate of ion collisions with the detector That is, a short intense burst of ions will cause pulse pileup even if the average rate of ion influx is low

Solution

The GSI ETA feedback control allows lower count rates to be specified so as not to push the cascade current beyond the 10% bias limit The data acquisition board is designed to handle 10 ns pulses from the preamp Presently the GSI system does not have the higher speed preamp incorporated into current VG systems

Memory in Torches, Spray Chambers and Cones

Problem

Memory of many elements from a sample that has just been analyzed will carry into the subsequent samples This memory may take hours to decay to an acceptable level

Discussion

The conventional ICP Mass Spectrometer setup uses a Scott spray chamber with a Fassel Torch made of quartz This combination is fine for extremely dilute solutions but fails when large concentrations of analyte are aspirated into the system
The nebulized sample traveling from the spray chamber to the torch injector tip experiences an increasing temperature gradient and a large surface area of quartz As the flow moves the contained particles may collide with the wall and be removed from the flow The residence time of the particles on the quartz is governed by many factors and is not infinite Thus later sample flow will capture particles released from the quartz surface which will become memory located in the torch

Cone memory is memory generated by the sputtered material being released and entrained in the plasma flow through the cone orifices The typical memory decay between samples for the standard spray chamber and torch is about three orders of magnitude or 0 1% of the original sample

Solution

The design of the electrothermal furnace and torch was done to reduce memory by at least six orders of magnitude between samples. The feedback control limits the ion flux out of the plasma to eliminate cone clogging and hence a source of memory

HARDWARE/SOFTWARE DEVELOPMENT

Development of a Tantalum Furnace

Work done studying the characteristics of a prototype electrothermal furnace design demonstrated carbon to be an unsuitable surface from which to attempt the atomization of samples. The primary problem is precision. The unpredictable nature of the carbon surface during atomization precluded generating equivalent quantitative data for the same sample in successive runs. This result dictated another suitable surface be found from which atomization could take place. To this end tantalum metal was chosen. The properties allowing tantalum to be chosen include.

(1) Essentially a monoisotopic element (99.988%)

(2) High atomic mass (180.9480)

(3) Very refractory (high melting temperature)

The furnace design is as follows. Two copper electrode blocks have a carbon annular ring between them. When energized, the carbon ring is heated from ambient temperature to greater than 2600C depending on the power applied. Inside this carbon ring is a cylindrical tube with a narrow snout at one end made of tantalum and inside the tube a small tantalum sample spoon may be inserted or retracted from the rear. With the spoon inserted, the furnace becomes a small black body oven in which the sample is uniformly heated until atomization occurs. A variable flow of carrier gas (with or without a vapor pressure enhancer included) is passed over the spoon through the tantalum tube to carry the atomized sample directly into the plasma directly adjacent to the furnace. The complete injection nozzle for the plasma is also constructed of tantalum. The only glassware remaining in the system is the torch glass inside the RF coil.

Principles of Operation

The GSI Electrothermal Furnace is an atomization furnace and an inductively coupled plasma ion gun all in one unit. The body of the furnace is constructed of tantalum metal (99.99% pure min). Surrounding the oven body is a cylindrical heating element of graphite which is clamped between two large, water cooled copper electrodes. A graphite heat shield surrounds the heating element to contain heat more efficiently within the oven during operation. Samples are introduced to the oven on a small retractable spoon which is breech loaded into one end of the oven. The spoon is also constructed of tantalum. A flow of

gettered argon equivalent to the nebulizer flow in a conventional ICP torch flows over the spoon through the atomization furnace carrying vaporized sample from the furnace to the plasma.

The plasma torch has been uniquely constructed from the same tantalum pieces that comprise the atomization furnace. In this way the shortest possible distance from furnace to plasma has been created. This is the prime contributor to the extremely low memory characteristics of this design. The only quartz in the system is a single outer plasma containing jacket between the load coil and the plasma. Careful design of the furnace body and injection nozzle (equivalent to the quartz injection tip in a conventional torch) allows cool plasma gas to flow backward over the outside of the tantalum oven body but inside the graphite heating element. This eliminates any possibility of unwanted material from the body of the oven or the outside atmosphere getting entrained into the analyte flow. This also prevents material being swept from the plasma and condensing on the body parts of the furnace reappearing later as memory.

Repair and Maintenance

The GSI Electrothermal Furnace has been designed to require only minimal maintenance. Periodically the quartz barrel which contains the plasma will have to be replaced due to recrystallization and shattering of quartz when in the RF field. O-rings are used several places within the furnace for sealing gas flows, coolant flows, and aligning the quartz barrel to contain the plasma. All these O-rings are viton with a hardness of 75 durometer. The graphite heating element and heat shield should be occasionally inspected for wear and development of cracks. With proper care and use the heating element will last indefinitely, however, graphite is very delicate material and can easily be broken with misuse.

The tantalum oven body and sample holding spoon are the most susceptible parts of the furnace. Under no circumstances should any gas containing oxygen in any concentration be fed through the oven. Tantalum is a tenacious getter of oxygen and turns to a crumbly white powder when exposed to oxygen at elevated temperatures. The small volumes of acids and aqueous material pipetted onto the sample spoon will eventually erode the spoon due to oxidation. The life of these two parts depends primarily on the type of samples and chemistry of solvents introduced to the oven. With time the tantalum oven body will recrystallize into hexagonal platelets and crumble. This is most aggravated when carbon is present. All replacement parts are available from GSI.

Furnace Use

The breech of the furnace is pneumatically opened and closed to retract the spoon for sample loading The pneumatic piston is actuated by the furnace open/close switch on the instrument front panel This switch energizes gas flow solenoids allowing gas flow to the piston When closing the breech block holding the tantalum spoon should smoothly engage the fitting in the large electrode block If it does not, the nylon fitting coupling the spoon holder to the actuating piston should be gently stressed in the appropriate direction to allow the breech blocks to engage. After a short usage period the nylon fitting will take a "set" and provide reliable breech closing

Connections

Electrical connections are as follows: the positive terminal from the GSI Electrothermal Furnace Power Controller goes to the ground furnace electrode block which is the one directly bolted to the blue frame of the furnace The negative terminal from the controller is connected to the insulated furnace electrode block which is the one mounted on the three metal rods by nylon insulation spacers

Input argon is required in two places At the tantalum plasma nozzle input and at the carrier gas input on top of the tantalum spoon holder assembly Nominal flows providing the best results have been found at about 16 liters per minute for the plasma nozzle and about 1 liter per minute for the carrier gas flow

Cooling water is input in series through three of the furnace blocks The input should be to the round front block shielding the tantalum plasma nozzle The output from this block goes to the input of the ground furnace electrode block and finally the output from the ground electrode block goes to the input of the electrically hot electrode block The output from this block goes to the drain

Development of the Furnace Controller

Complete manual control of the GSI Direct Electrothermal Atomization Furnace is impossible. Therefore, the furnace is controlled by the GSI Feedback Furnace Controller. This device is used to control the power applied and consequently the temperature of the furnace. An IBM PC-XT is used to control all instrument functions including furnace control. The prototype design uses a power triac solid state device and the necessary digital electronics to convert an eight bit output word from the computer into a power level for the furnace. Raw power is brought to the controller via a 208 volt line. This is converted to 7.5 volts using a 5kVA transformer with appropriate core biasing to drive the furnace load of about 15 milliohms.

Development of Controlling Software

The development of controlling and data acquisition software for the GSI Direct Electrothermal Atomization Furnace, the GSI Feedback Furnace Controller and the GSI Real Time Data Buffer Card was contracted. The software must be able to collect and store data in real time, analyze the data sufficiently to determine appropriate furnace control and interface with existing instrument control and data handling software.

Control of the instrument during data collection is performed in the way VG Isotopes originally designed the VG Plasmaquad mass spectrometer to operate. The GSI software, in the design phase, works in parallel with the VG Plasmaquad data collection software but with several additions. Parameters governing a sample analysis are completely set by the GSI software. These parameters are then passed to the VG Plasmaquad instrument control software for the initiation of a sample run. In addition, the initial furnace control parameters are set in the furnace controller.

Actual data collection parallels the VG Plasmaquad system by tapping the output signal from the preamplifier of the VG instrument. The data is produced by successive sweeps across the mass region of interest. After each sweep or set of sweeps (controlled by initial parameters) the computer then decides whether or not the furnace may be incremented in temperature. This decision is based on the number of ion counts in each channel. If any mass channel in the mass scan region exceeds a preset threshold value for that channel, the material is deemed to be atomizing at too great a rate and the furnace is not allowed to increment in temperature. The furnace will be held at its present temperature value until all mass channel values are within their respective thresholds. All data is written to the hard disk in real time.

Data Acquisition Hardware/Software Operation and Interface

In August 1986, the VG mass-spectrometer was equipped with an Olivetti Z8000 based CPU and the standard Tracor-Northern multichannel analyzer The MCA was accessed from the Olivetti through a IEEE-488 bus The time required to poll and extract the data stored in the MCA was about 3 seconds. This data extraction needed to be done once for each sweep, or about every 0.2 seconds (2048 channels/sweep * 100 uSec/channel) This forced a data collection path to be developed, that was parallel to the MCA, but allowed real time access to the data

Once this decision for custom electronics to collect the data was made, the next decision was which CPU and language to choose for the host computer and the software. Since VG already had an IBM PC based system that replaced the Olivetti Z8000 and their new software was written in Logitec's Modula-2, this was examined and the CPU and language were determined to be very desirable

At this stage, late August and early September 1986, a search for off the shelf hardware was conducted that would allow a direct memory access (DMA) of the data from the collection device to computer memory to occur No reasonable DMA boards were found
The decision was then made to input data with a parallel I/O card (made by John Bell Engineering) and collect the data on a custom in-house board. The John Bell board required one slot in the IBM and the in-house board required the end slot and the space next to it

The inputs to the data collection board are.

1) the next channel pulse (from the PQ controller).
2) the count pulses (from the La Croix amplifier)
3) control signals from the host computer (through the John Bell card)

The outputs from the data collection board are
1) eight (8) bits of temperature control to the furnace controller (allowing 256 levels of power/temperature), controlled from the IBM computer
2) data and control signals to the IBM through the John Bell board.

The heart of the data collection board consists of a set of two counters. the current temperature counter and the current count. The current counter is a free running event counter that counts pulses from the La Croix amplifier On a next channel pulse the current count is passed into an on-board FIFO and the

counter is reset When a start of sweep is detected, the current temperature is passed into the FIFO The data from both of these counters is sixteen (16) bits wide The temperature data has the top two bits forced on, this marking is used align the beginning of sweeps and control the summation of data into temperature bins The count data has the high bit clear

Whenever data is present in the FIFO, the IBM is notified through a control line The IBM then extracts data from the FIFO through the John Bell card

The VG software was modified to work with two GSI routines The first routine, METHOD, is the main control routine The second routine, GETDATA, is the data collection, summation, and storage routine GETDATA is called by METHOD, after the mass-spectrometer begins collecting data

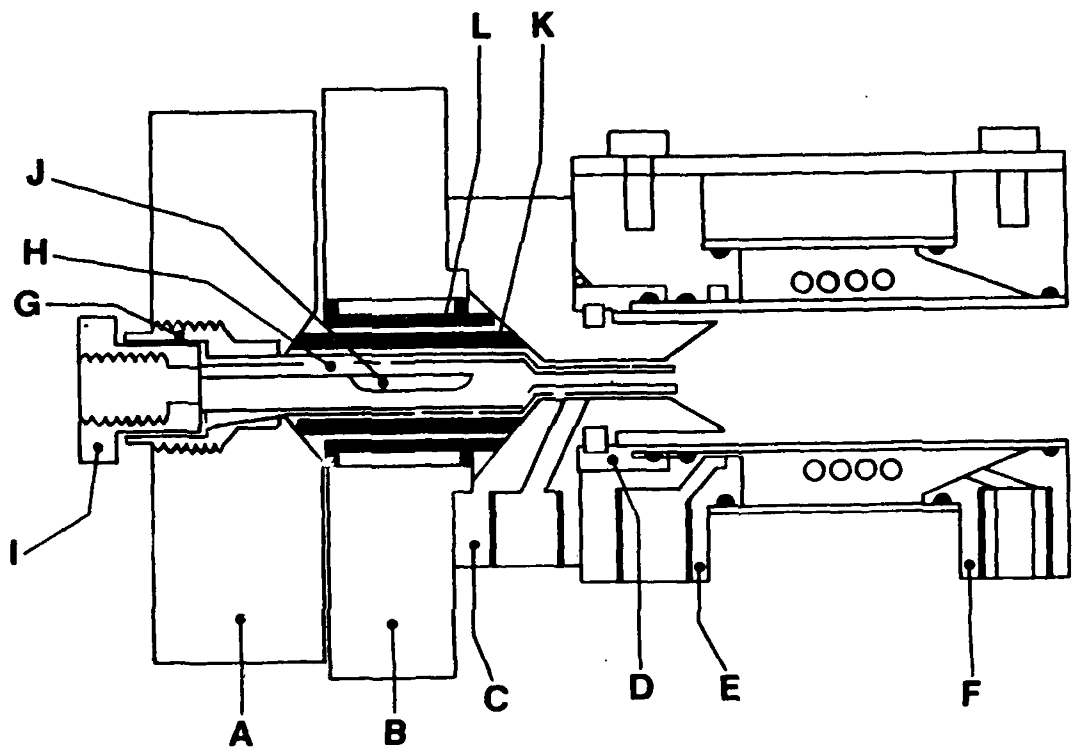
METHOD prompts for the type of action requested

1) data collection or
2) data analysis

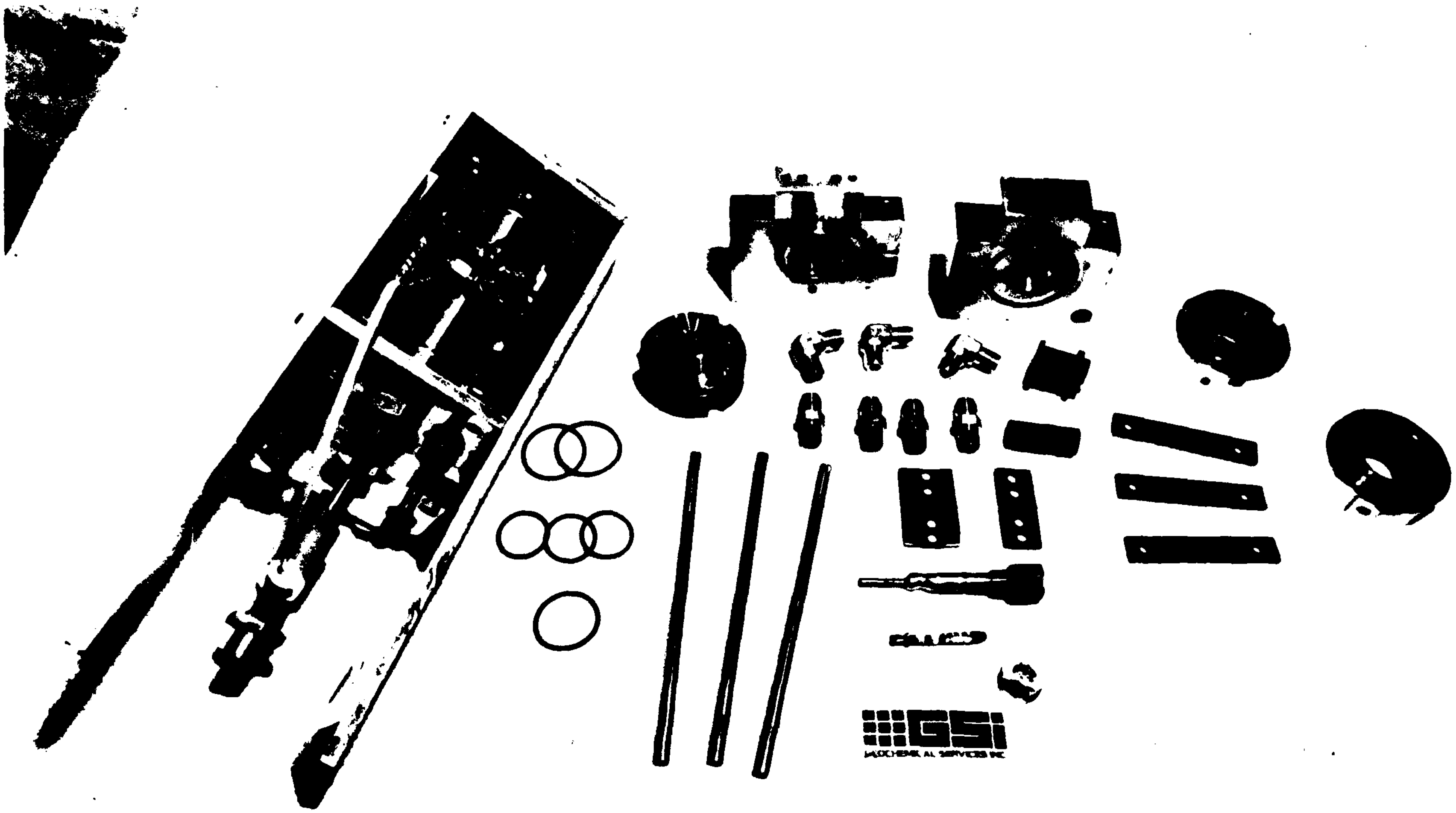
In the data collection mode, METHOD prompts for and inputs a method or control file A method file contains the parameters needed to run the mass-spectrometer through the VG control software, control the power to the furnace, and control the summation of the data Method files are created and modified off-line with a text editor The furnace control is achieved by allowing the temperature/power setting to be incremented by a scheduled amount, only when the counting rate for each channel in the sweep falls below thresholds set in the method file Additional lower and upper limits on the number of sweeps at each temperature/power setting are imposed Data is summed within a temperature setting into bins The number of sweeps within each summation bin is controlled E g , one sweep per bin allows very fine granularity in the data and many bins, while at the other extreme, all sweeps at one temperature summed into one bin allows 256 bins total The amount of granularity required is determined by the disk space available Each channel is summed into a 32 bit integer in the summation bins, 2048 channels * 4 bytes = 8kb/summation bin of data + a header The original disk space allocated was 10 Megabytes This gave 10M/8K or about 1100 bins total Each scan required 10 Megabytes of storage!

The data analysis allowed reduction of the data into a VG formatted raw data file, analysis of the temperature data with the background (zero temperature) subtracted from the remainder of the data, and plotting of the raw data or zero reduced data

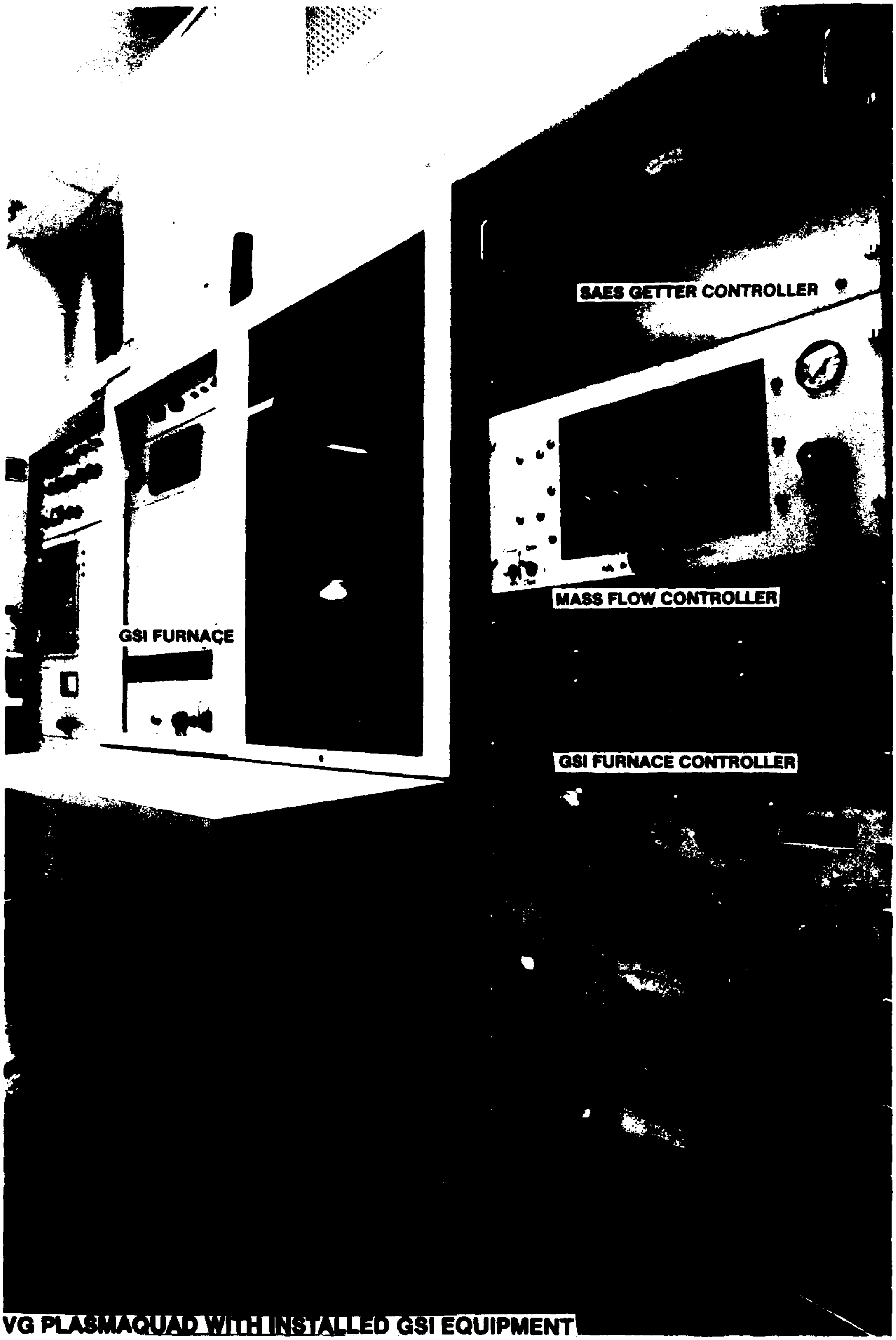
TORCH/FURNACE ASSEMBLY



A - Moveable Block	E - Cooling Manifold	I - Breech Block
B - Oven Block	F - Outer Manifold	J - Sample Spoon
C - Plasma Nozzle	G - Tube Holder	K - Heater Element
D - Sealing Ring	H - Tantalum Tube	L - Heat Shield



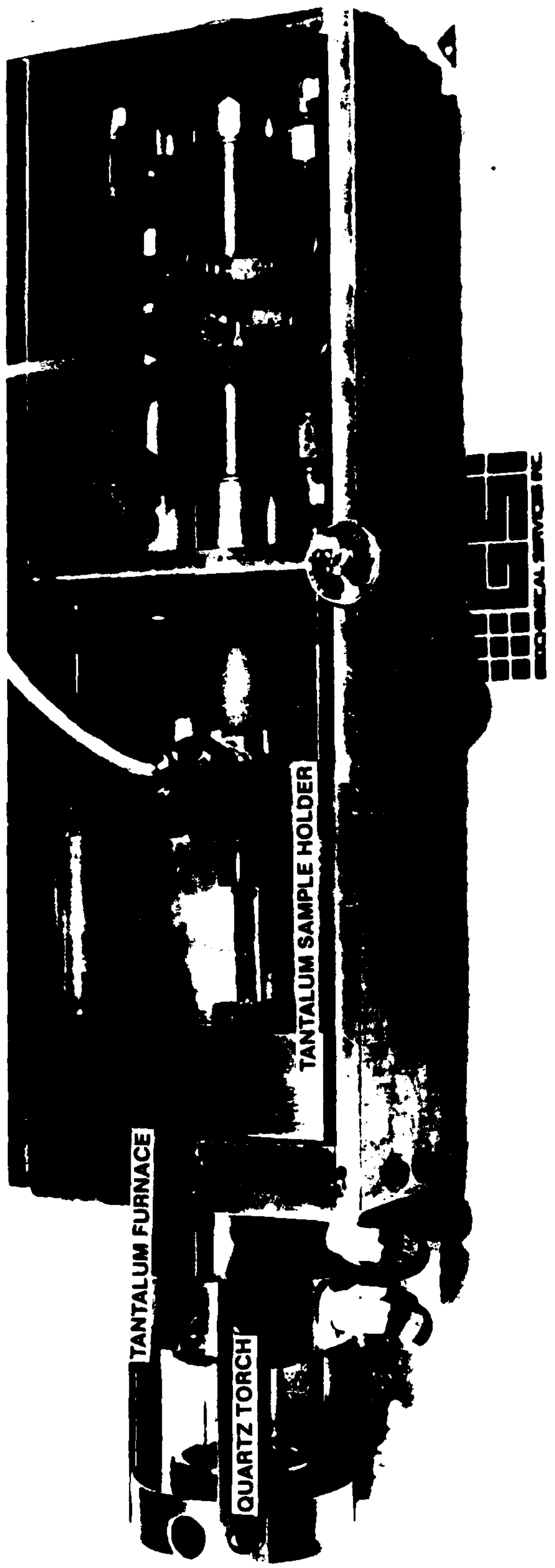
GSI FURNACE/TORCH ASSEMBLY



VG PLASMAQUAD WITH INSTALLED GSI EQUIPMENT

GSI DATA ACQUISITION ELECTRONICS
(FITS IBM PC EXPANSION SLOTS)

DATA GRAPHICS USING GSI SOFTWARE



GSI FURNACE/TORCH ASSEMBLY

GSI ICP/MS SOFTWARE

USERS MANUAL

The GSI Package

The software package includes several programs which are written in modula 2 and in IBM assembly This package has been designed to be compatible with the standard VG Plasmaquad ICP/MS software The instrument is still brought to operational mode and returned to standby mode using the VG Plasmaquad software

The GSI package consists of the following files

(1) m2 exe
(2) getdata exe
(3) dataread lod
(4) method lod
(5) turbo exe
(6) turbo msg
(7) markbad com
(8) gwbasic exe
(9) plot bas
(10) method txt
(11) config sys
(12) autoexec bat

With these twelve programs you enter another dimension in ICP/MS data collection

This software allows you to collect data in three dimensions in real time from your mass spectrometer The dimensions are atomic mass units, ion counts and temperature of the electro-thermal atomization furnace In this way you are able to observe directly when each element volatilizes from your sample of interest You have infinite flexibility in programming the parameters under which data is collected This is done by means of a method file This file is created using any word processing editor you have available (we use the Turbo editor)

In this file you specify all the parameters necessary to run the instrument and control the furnace during the run You then start data collection and watch!

How the system works

The system consists of several pieces of hardware and soft-ware The GSI Direct Electrothermal Atomization Furnace replaces the conventional ICP torch and is controlled by the GSI Feedback Furnace Controller Data collection is performed using the GSI Real Time Data Buffer Card which is installed in your IBM PC-XT or PC-AT The software then collects data analyses it to determine the rate of atomization of the sample and controls power to the furnace The advantages of this system over the

standard VG software and hardware are

(1) the detector remains within linear counting range

(2) maintains a stable vacuum plasma interface orifice

(3) matrix effects in the plasma are controllable

(4) allows resolution of isobaric interferences

System requirements

In order to run the GSI ICP/MS software your computer must be an IBM PC-XT or PC-AT or compatible You must have a regular monochrome monitor as well as the Princeton (or NEC multisync) monitor You will also require at a minimum a 20Mbyte hard disk drive and preferably a 30 Mbyte drive

Getting started

To begin, load the two programs config sys and autoexec bat in the root directory of your hard disk and reboot the system

Load the files

```
C:\>copy a autoexec bat
C:\>copy a config sys
```

Reboot the system by pressing the CTRL, ALT and DELETE keys simultaneously Next create a subdirectory called \M2 as follows

Creating \M2 subdirectory

```
C:\>md m2
```

Go into this subdirectory

```
C:\>cd m2
```

Now load the following programs from the floppy disk

(1) m2 exe
(2) getdata exe
(3) turbo exe
(4) turbo.msg
(5) markbad com
(6) method txt

This is done using the copy command. The LOD modules from this package must be loaded in a subdirectory labeled \M2LOD. Do this as follows

Return to the root directory
C \M2>cd\

Create subdirectory \M2LOD
C \>md m2lod

Go into \M2LOD subdirectory
C:\>cd m2lod

Now copy the LOD files from the floppy into this sub- directory.

The next step is optional but we prefer it for housekeeping purposes on the hard disk. Return to the root directory as above and create another subdirectory called \VG. Go into this subdirectory and copy all the original VG Plasmaquad .LOD modules and the VG Plasmaquad version of m2 exe from the root directory into this subdirectory. Then return to the root directory and delete all of the VG Plasmaquad files in this directory. You are now ready to run (assuming all the necessary hardware is installed correctly on your instrument)

To run, start the instrument normally using the VG Plasmaquad software. When stable and running break out of the VG Plasmaquad software and return to MS-DOS by pressing CTRL BREAK

Using GSI ICP/MS software

Go to the \M2 subdirectory
C.\M2>cd\m2 (return)

Run the program getdata exe
C \M2>getdata (return)

Run the program method lod

C:\M2>m2 method (return)

The method program is menu driven and quite similar to the VG Plasmaquad menu driven programs. The method file is created using the turbo word processor and is covered in the method file section of this manual. In order to run select the menu choice listed in the initial screen of the method program which displays as follows.

```
GSI DMA SOFTWARE
Copyright 1986  Geochemical Services, Inc

R      Read method file

C      Control and run from a method file

V      VG data format write of zero sum data

Q      Quit and return to DOS

              Enter your selection [R,C,V, or Q]
```

R displays a method file on the screen for you to read. This is useful in reviewing your sample analysis method.

C passes analysis parameters to the instrument at the beginning of data collection and controls the furnace dwring sample analysis according to the method file. A normal termination of the instrument and data storage in a background corrected VG Plasmaquad binary data file occurs at the end of data collection.

V allows the hard disk data storage area to be interrogated and a background corrected VG Plasmaquad type binary data file is written.

Q exits the GSI ICP/MS software and returns to the MS-DOS operating system

Creating and editing method files.

Complete control of data collection and the electrothermal atomization furnace is done by means of a method file. In this file all the parameters that are required to run the VG Plasma-quad during data collection and control the furnace during this time are specified in a method file. The format of a method file is as follows

```
2048 0250       channels per sweep and dwell time(usec)
0000            default max sweeps per summation buffer
0000            default min sweeps per temperature step
0000            default max sweeps per temperature step
0000            default # of pulses per temp step
0210            maximum furnace increment before shutoff
0125            # of initial sweeps to throw away
0000 0000 0010 0100 0001 0120
                min/max tmp,min/max sweeps,tmp inc,sums per step
(this control line may be repeated several times)

-1              start amu and threshold definitions
0007 0125       starting and ending amu for scanning
0023 0027 0500  starting and ending amu, threshold
```

The first line defines the number of channels per sweep the quadrupole has and the dwell time at each channel. The next four lines define default parameters which would be used only in the simplest methods. With these four values you can define a simple staircase ramp for data collection. The sixth value is the maximum power increment the furnace is allowed to attain. The range is from 0 to 255 representing 0 to 100 percent power to the furnace. The number of throw away sweeps defines how many of the initial sweeps are to be ignored. This feature allows you to ignore sweeps when the detector is first turned on to allow for any transients or initial fatiguing that may occur

(a) furnace control parameters

The next six numbers in a line define control parameters for the furnace and are repeated as necessary in order to produce the desired furnace temperature ramp for the particular analysis

being performed The first two numbers in each of these lines define the starting and ending temperature for the part of the temperature profile controlled by the respective lines These numbers must range between 0 and 255 The next two numbers in each of these lines define the minimum and maximum number of sweeps across the mass spectrum that may be collected at the present temperature increment before the furnace is commanded to the next temperature increment The fifth value in each line commands the size of the increments between successive temperature steps for the furnace in the temperature interval specified in that line The sixth value defines how many sweeps across the mass spectrum are collected in a histogram before the data is stored and the next histogram is begun

The -1 value defines the end of the furnace control data. The next line identifies the starting and ending values for the sweep across the mass spectrum and is specified in atomic mass units (amu). These values are calibrated from the VG Plasmaquad software calibration file resident on the hard disk The calibration may be updated using the VG Plasmaquad software

(b) feedback threshold control

The final set of lines with three values each define the feedback control threshold parameters. The first two values identify the region of the mass scan region to which the control threshold is applied and is specified in amu. The last value is the threshold value above which no mass channel inside the mass range for that threshold value is allowed to go. If the threshold is exceeded the furnace is held at its present temperature provided the maximum number of mass scan sweeps specified for that temperature has not been exceeded Any number of thresholds may be set but remember that thresholds specified after set thresholds in lines previous will be overwritten by the next threshold value if there is overlap

An example

```
0023 0067 0500
0064 0093 0800
```

In this example the region from amu 64 to amu 67 appears to be controlled by two threshold values However, only the last value - 800 - is recognized in this region of the mass spectrum.

(c) using the Turbo editor

T his editor is the Turbo Pascal editor and contains many features For those not familiar with this editor the following guidelines

To enter the editor

C \M2>turbo

Enter no (N) to the question do you want error messages - these messages are for the pascal compiler that is included with the editor. Unless you are writing pascal programs these messages are not useful. Next a menu with several choices will appear. Enter E to invoke the editor. Next you will be asked for a file to edit. You may enter either a preexisting filename or a new filename for the title of your method file. The file METHOD TXT included with this software may be used and edited as a model. To move the cursor the arrow keys on the numeric keypad of your IBM PC-XT or PC-AT are used. The home command moves the cursor to the beginning of the present line and the end key moves the cursor to the end of the present line.

There are two modes (present mode is displayed at the top of the screen) while editing insert and overwrite. Insert mode allows text to be inserted in preexisting text while overwrite mode simply overwrites preexisting text. Characters are deleted using the delete key of the numeric keypad. When in insert mode lines may be inserted or deleted using the enter and backspace keys respectively

To exit the editor the following sequence is necessary.

To exit to command mode hold down the CTRL button and type K. Then type D. The cursor prompt is now

>

To save your editing

>S

When finished saving

>Q

You are now back to MS-DOS and are ready to run the data collection software. It is a good idea to now copy method txt to another filename meaningful to the sample analysis it pertains to. In this way you may build a library of method files while maintaining the file method txt as a skeleton guide when editing

Processing data

The program method writes a binary data file equivalent to

the VG Plasmaquad raw data file except that a background constant for each mass channel in the sweep is subtracted from the data. These constants are determined by the number of background sweeps specified in the method file. Each of the stored mass scan sweeps are interrogated and the total sum of these sweeps on a channel by channel basis are divided by the number of sweeps making up the sum. Since statistically this value can lead to negative values in the data file, any value that is determined to be negative by this operation is set to zero.

The program "dataread" interrogates the hard disk storage area and writes a set of data files that store response versus temperature of the furnace for any desired amu.

ANALYTICAL PERFORMANCE

Several types of analysis were done in order to demonstrate that the software and hardware perform as designed Because of the contract time and money constraints, detailed methods development for the semiconductor analysis in the original proposal was not possible.

An analysis was done to demonstrate the ability of the system to resolve isobaric interferences over a temperature profile which was a major goal of the contract. Figure A shows the analysis of a sample containing both Cd and Pd. At amu 111, Cd shows a signal vs. furnace temperature At amu 106, both Cd and Pd have an isotope that can not be resolved on the normal mass spectrometer. Figure B shows the resolution of both Cd and Pd vs. temperature at mass 106.

Figures C through L show the responses of the rare earth elements vs. temperature. These elements are of interest for mining as well as the electronics industry With the normal spray chamber, oxides of the lighter rare earth elements can cause significant interferences with the heavier elements. With the temperature resolved system the oxides would be expected to be temperature resolved No oxides are present because of the lack of water in the sample introduction.

Figures 1 through 3 show data collected with software developed by GSI after the contract work. These outputs show the resolution of Hg and Pb at mass 204 on a complex United States Geological Survey reference standard, GXR-1. This standard has 4 ppm of Hg and 700 ppm of Pb. The sample was run as a 10% dissolved solid Figure 1 shows Hg at mass 208 Figure 2 shows the Hg at mass 202 Figure 3 shows Hg at mass 204 resolved against Pb at mass 204

PATENTS

Patents were applied for on the furnace/torch assembly and the feedback control system as described in the contract proposal. The concepts on which the patents were based were documented prior to the contract award, however the filing dates were after the award and some drawings developed during the contract period were used.

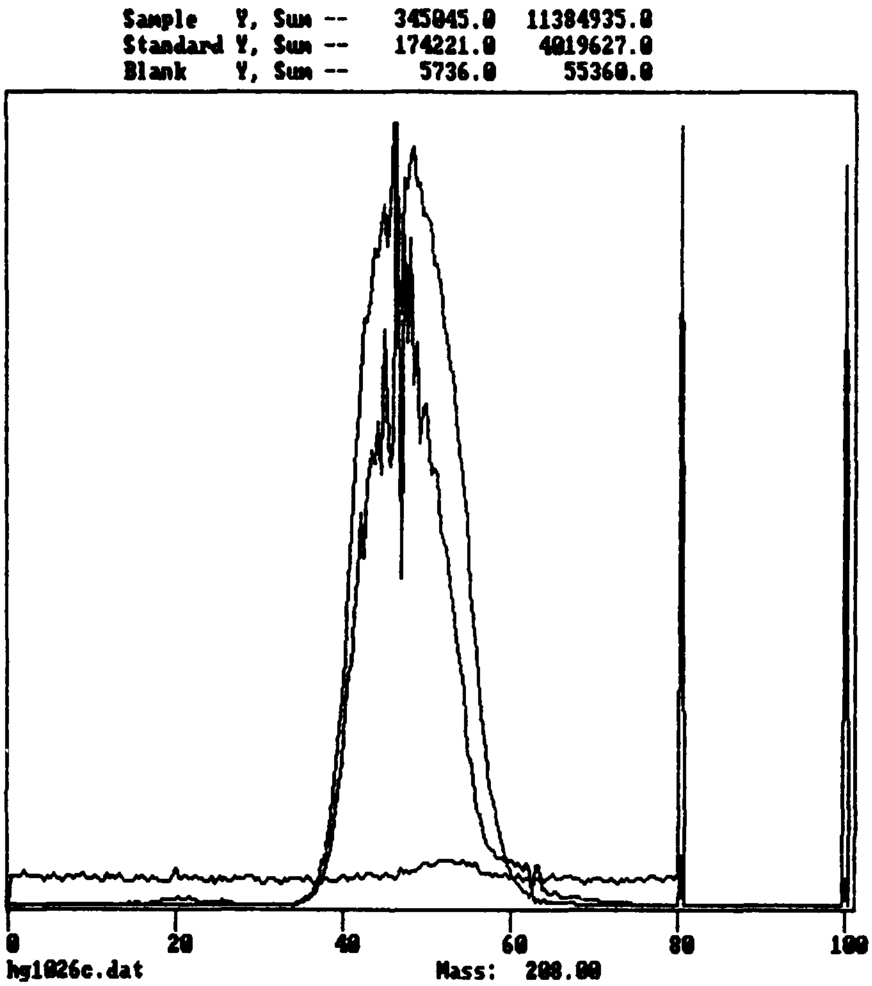


Figure 1: Temperature profile at atomic mass 208Pb. Three profiles are plotted: sample, standard and blank. Values displayed are the peak value are a single temperature and total integrated counts under the temperature profile respectively. The two spikes are temperatures 80% and 100% are due to integrated background during the furnace purge cycle at the end of analysis.

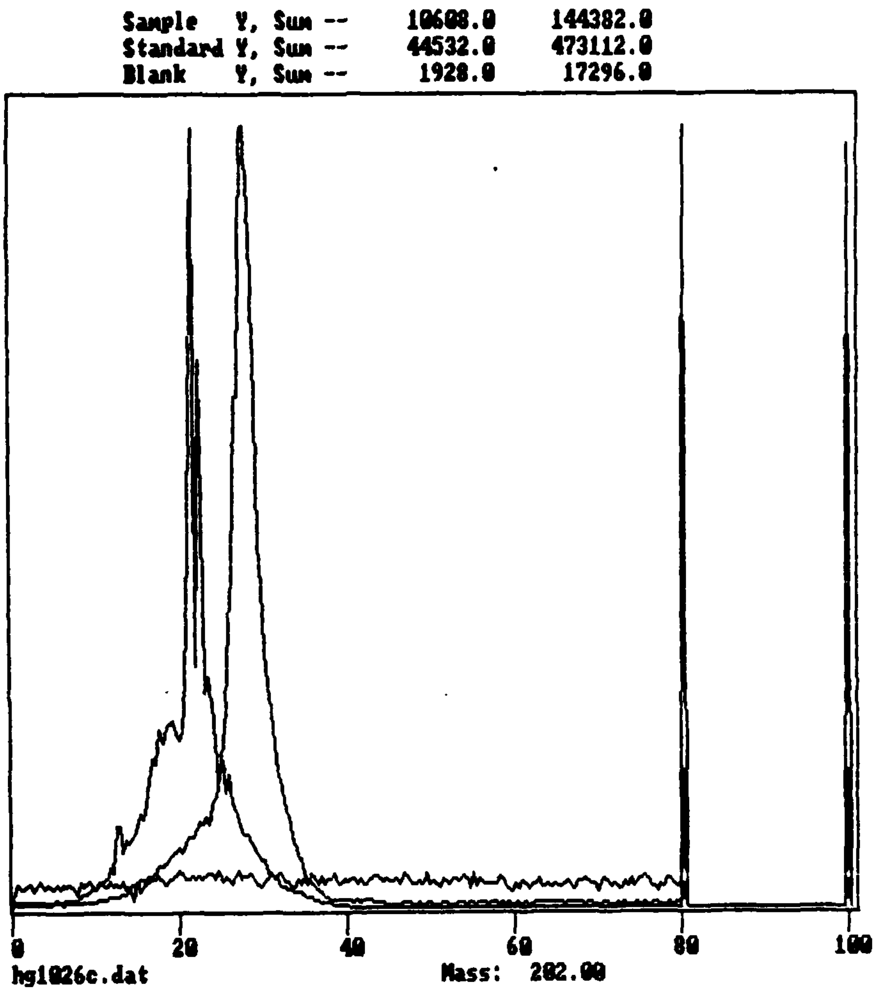


Figure 2: Temperature profile at atomic mass 202Hg. Plots are analogous to figure 1 with sample, standard and blank set. The two signal peaks are slightly offset due to matrix chemistry during analysis.

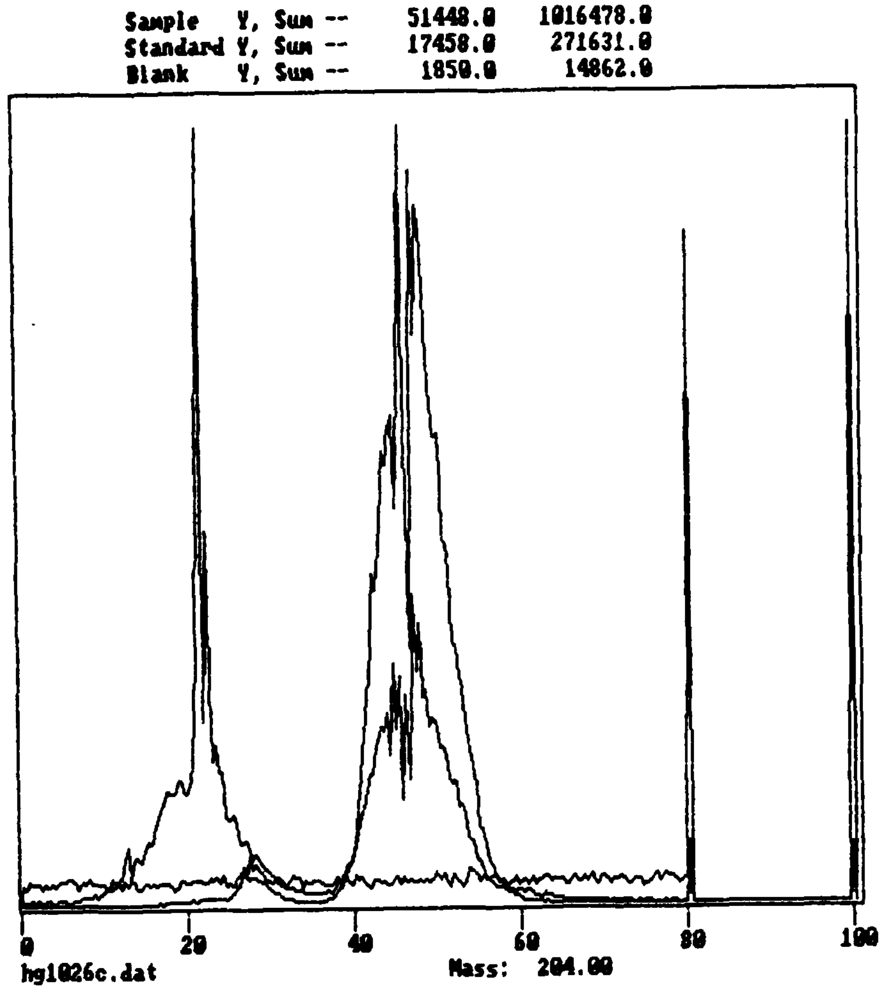
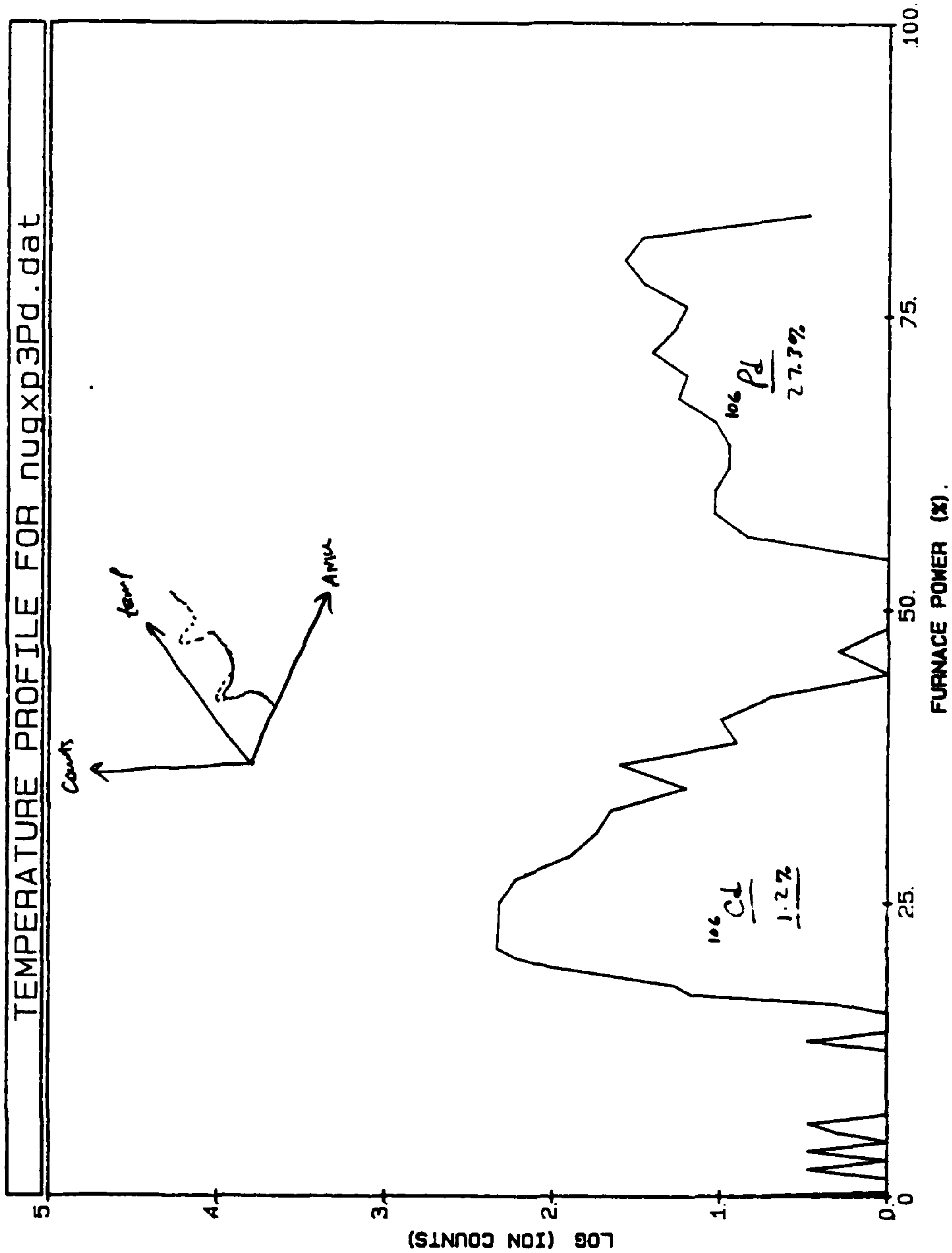
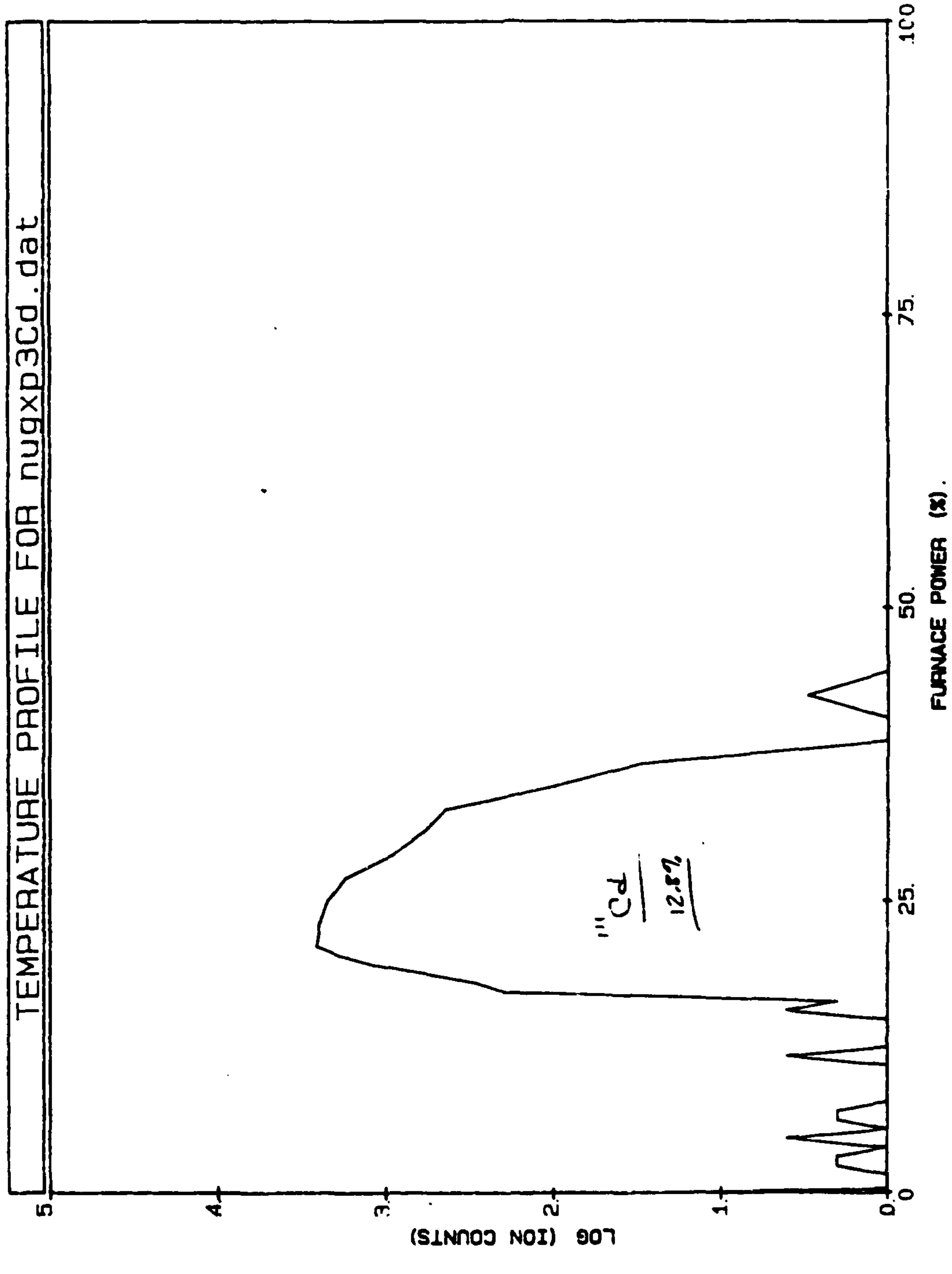
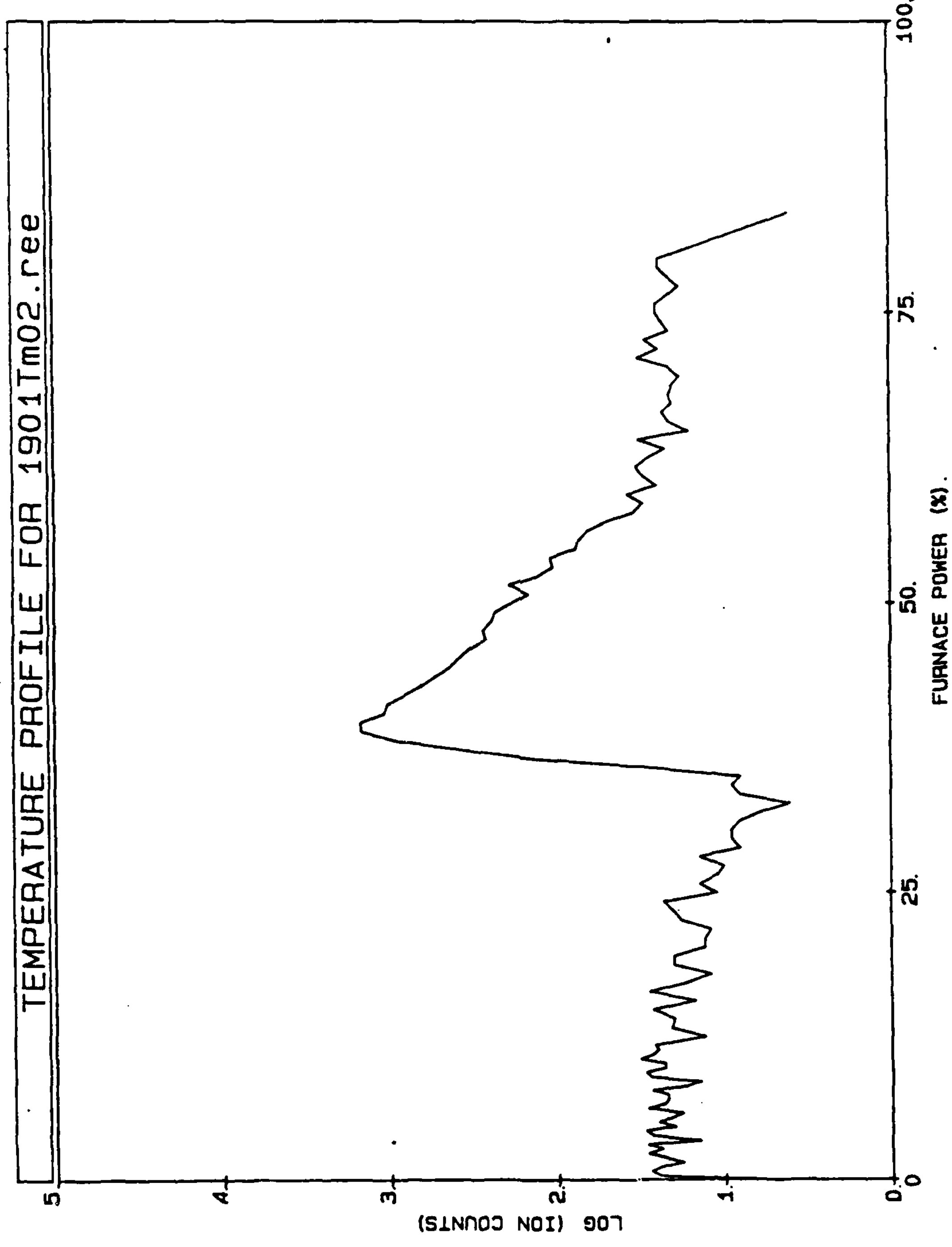
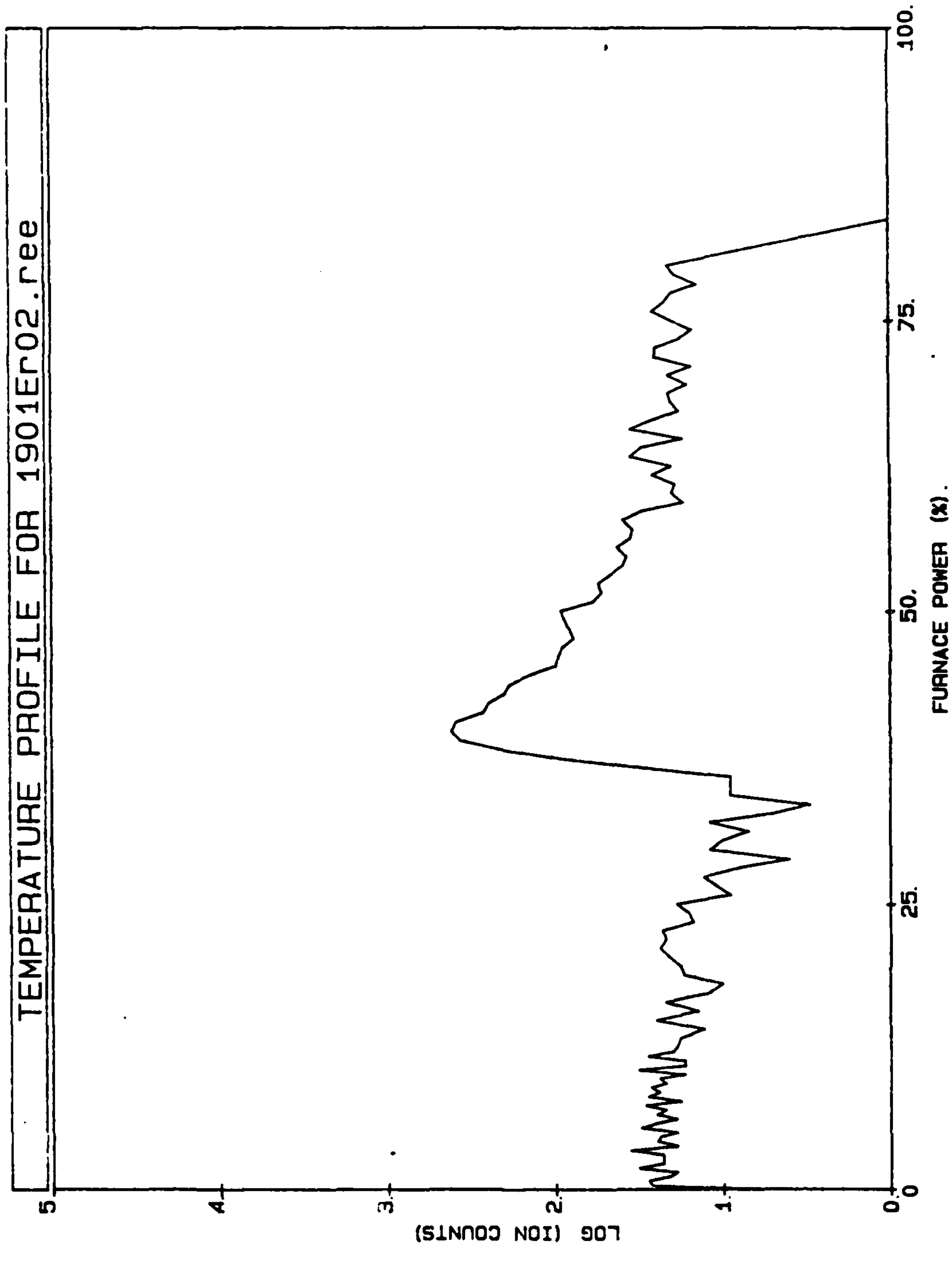


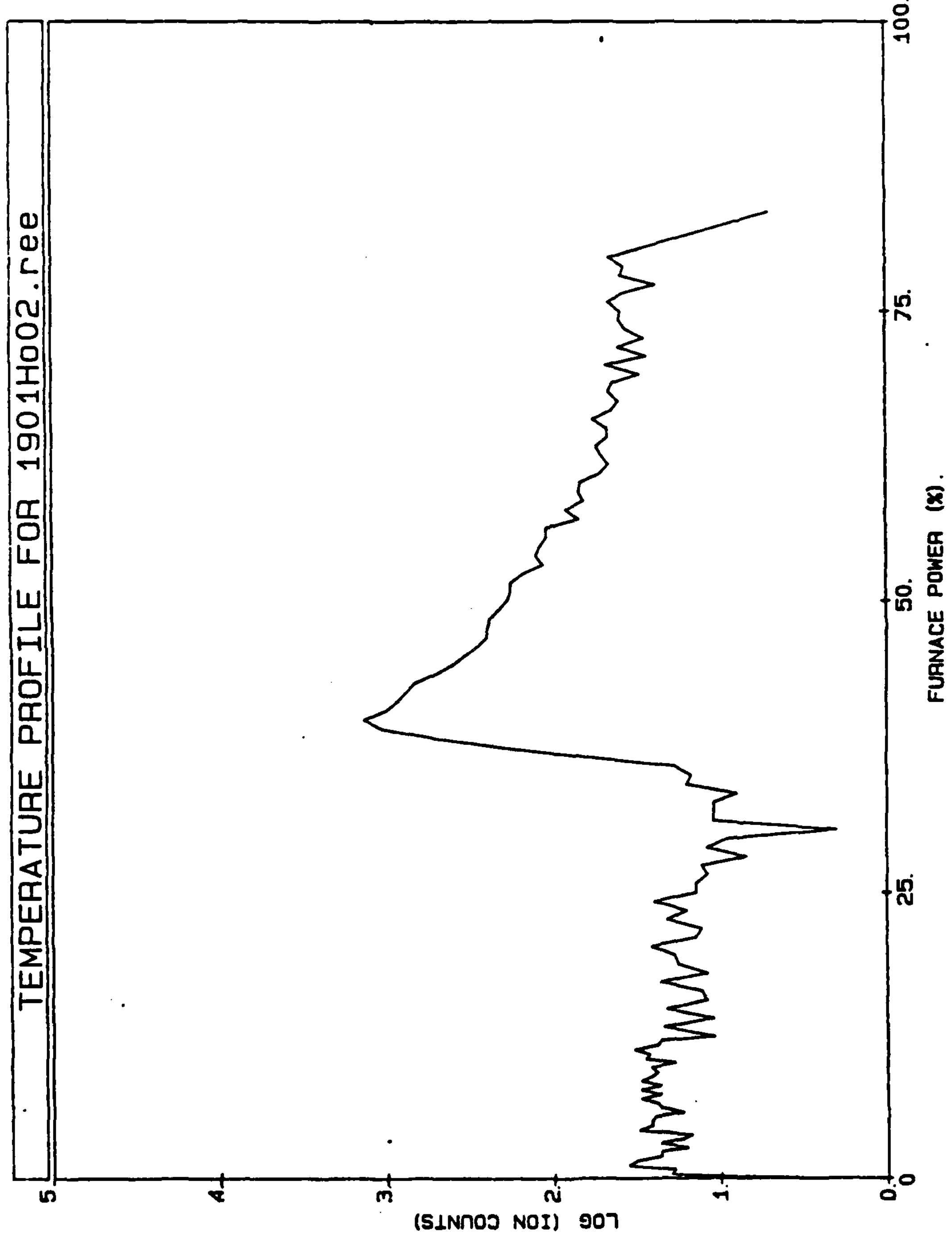
Figure 3: Temperature profile at atomic mass 204. This figure demonstrates the method of isobaric resolution between the 204 isotopes of Hg and Pb. Hg begins volatilization at about 10% power and ends at about 34% while Pb begins at about 39% and ends at about 60%.

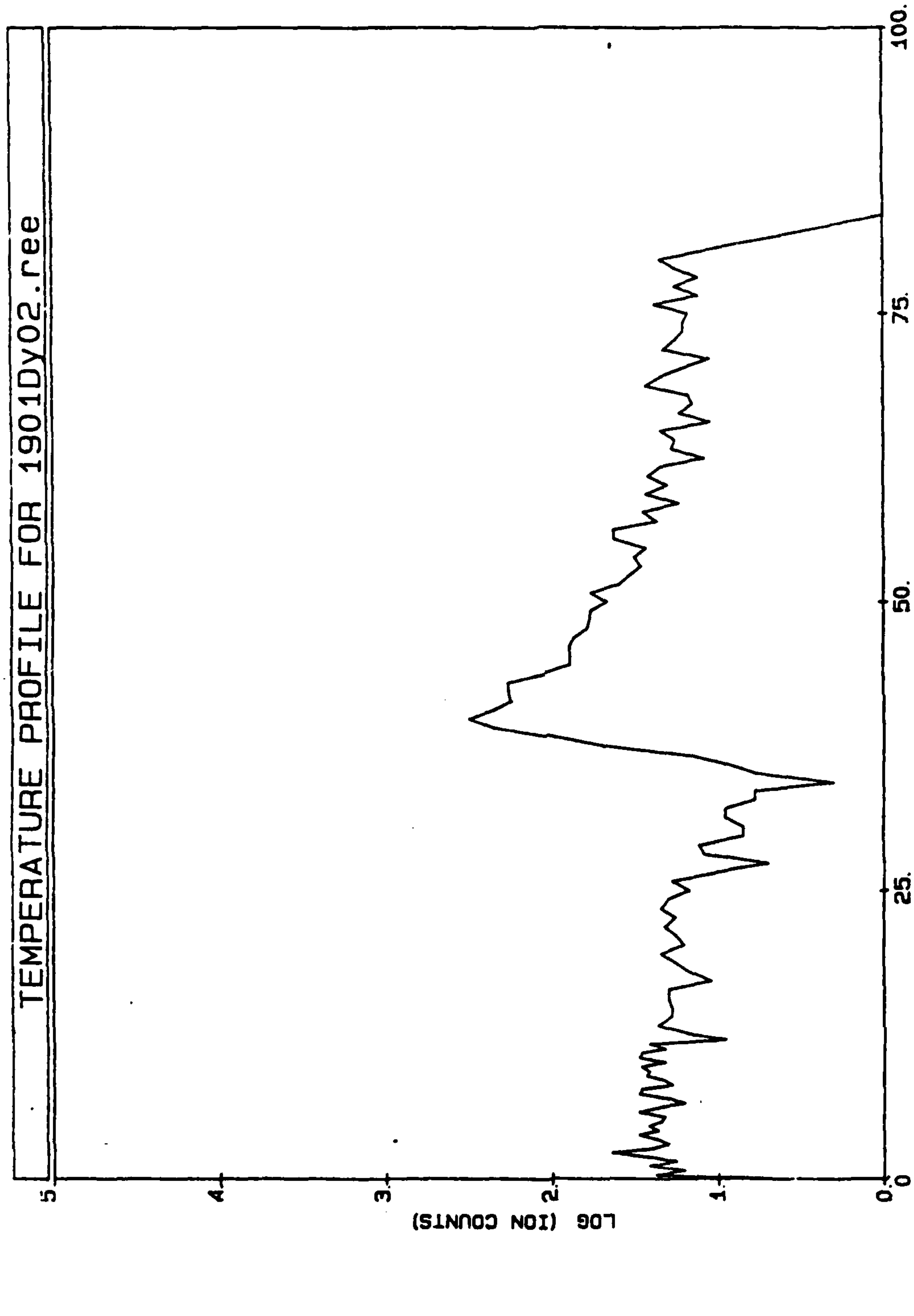

TEMPERATURE PROFILE FOR nugxp3Pd.dat
LOG (ION COUNTS)
FURNACE POWER (%)
0
1
2
3
4
5
0
25.
50.
75.
100.
106 Cd
1.2%
106 Pd
27.3%
Counts
temp
AMU

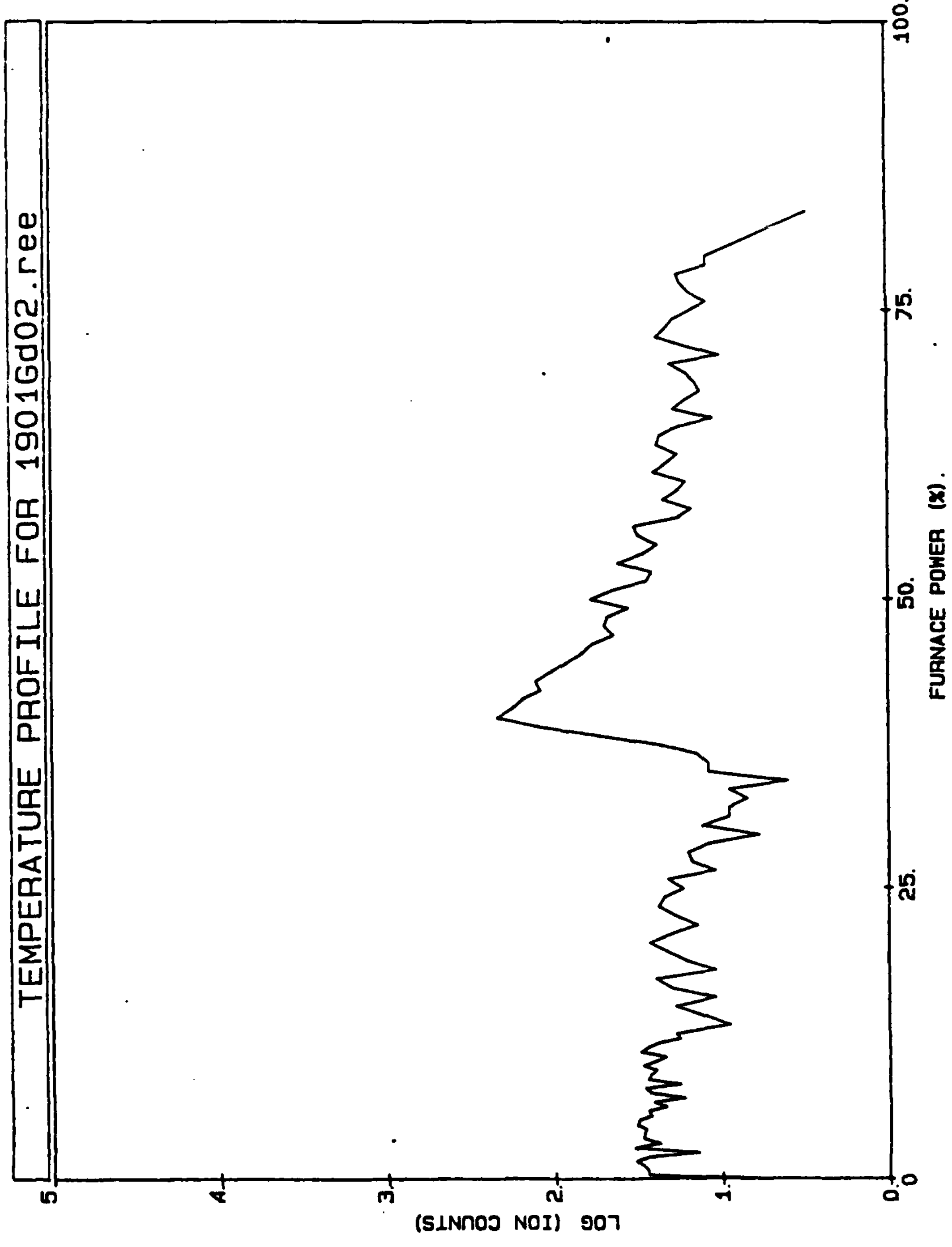

TEMPERATURE PROFILE FOR nugxp3Cd.dat
LOG (ION COUNTS)
FURNACE POWER (%)
0.
1.
2.
3.
4.
5.
25.
50.
75.
100
12.87

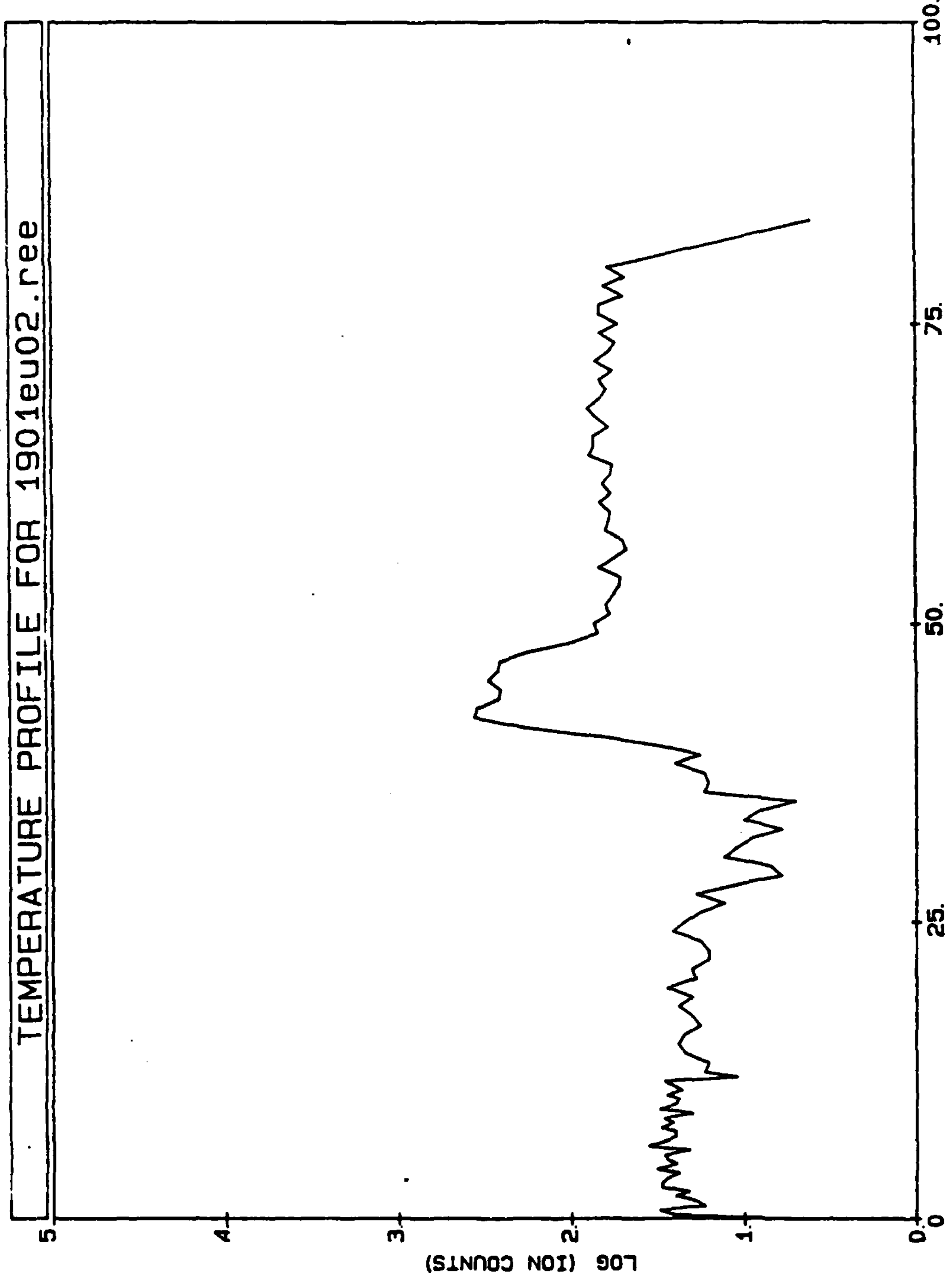

TEMPERATURE PROFILE FOR 1901TmO2.ree
LOG (ION COUNTS)
0
1
2
3
4
5
FURNACE POWER (%)
0
25.
50.
75.
100.

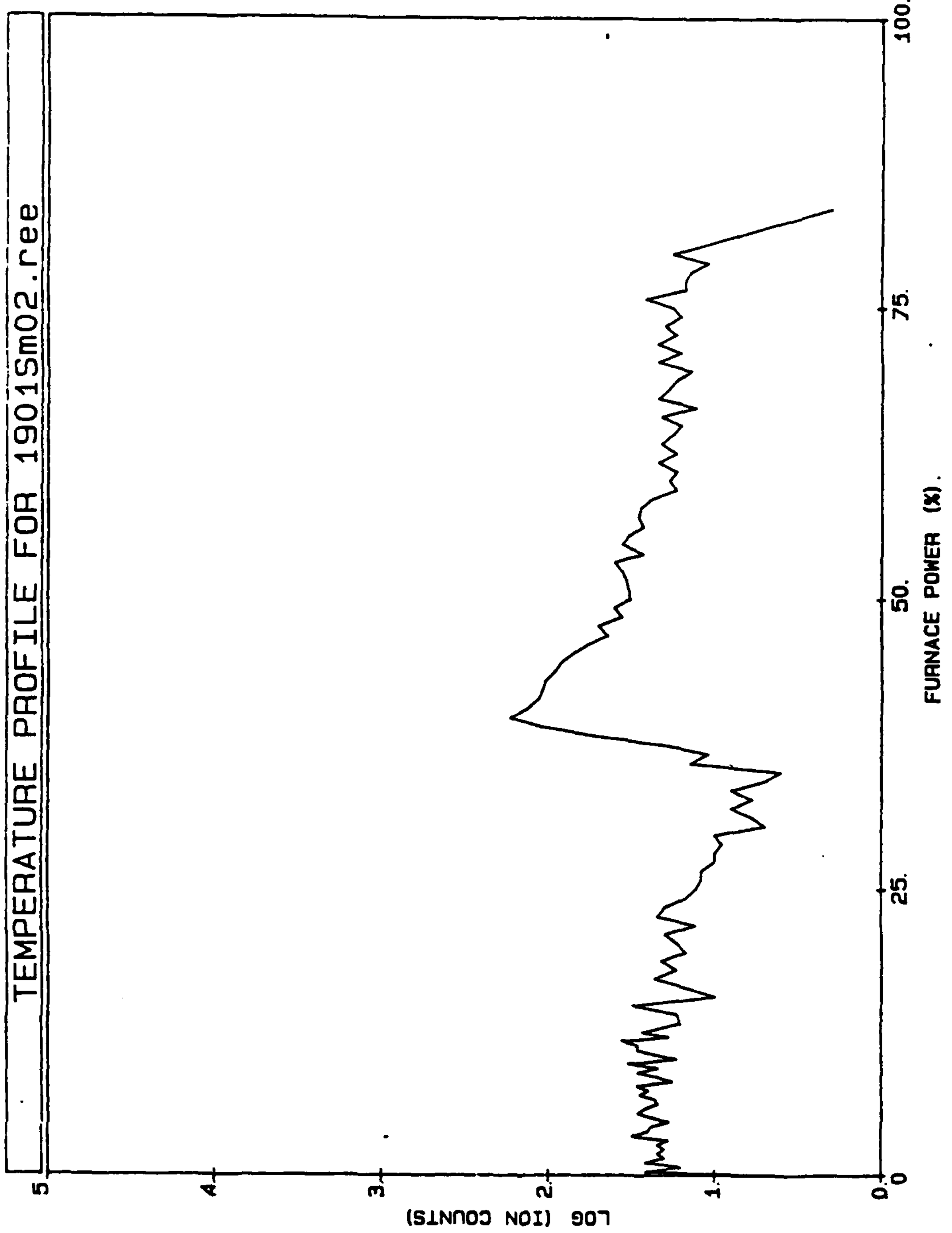

TEMPERATURE PROFILE FOR 1901Er02.ree
LOG (ION COUNTS)
0
1.
2.
3.
4.
5
FURNACE POWER (%)
0
25.
50.
75.
100.

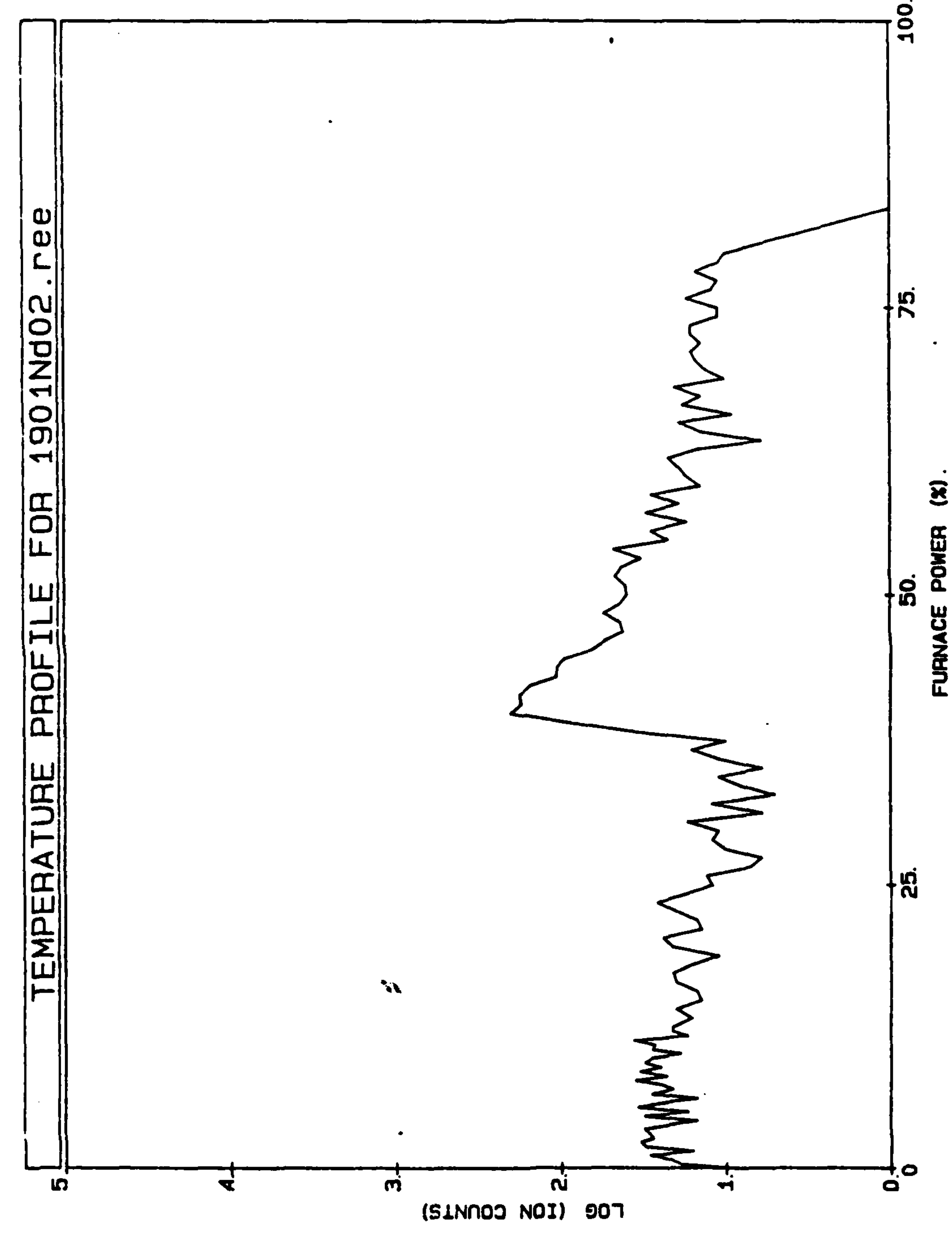

TEMPERATURE PROFILE FOR 1901Ho02.ree
LOG (ION COUNTS)
0.
1.
2.
3.
4.
5.
0
25.
50.
75.
100.
FURNACE POWER (%).

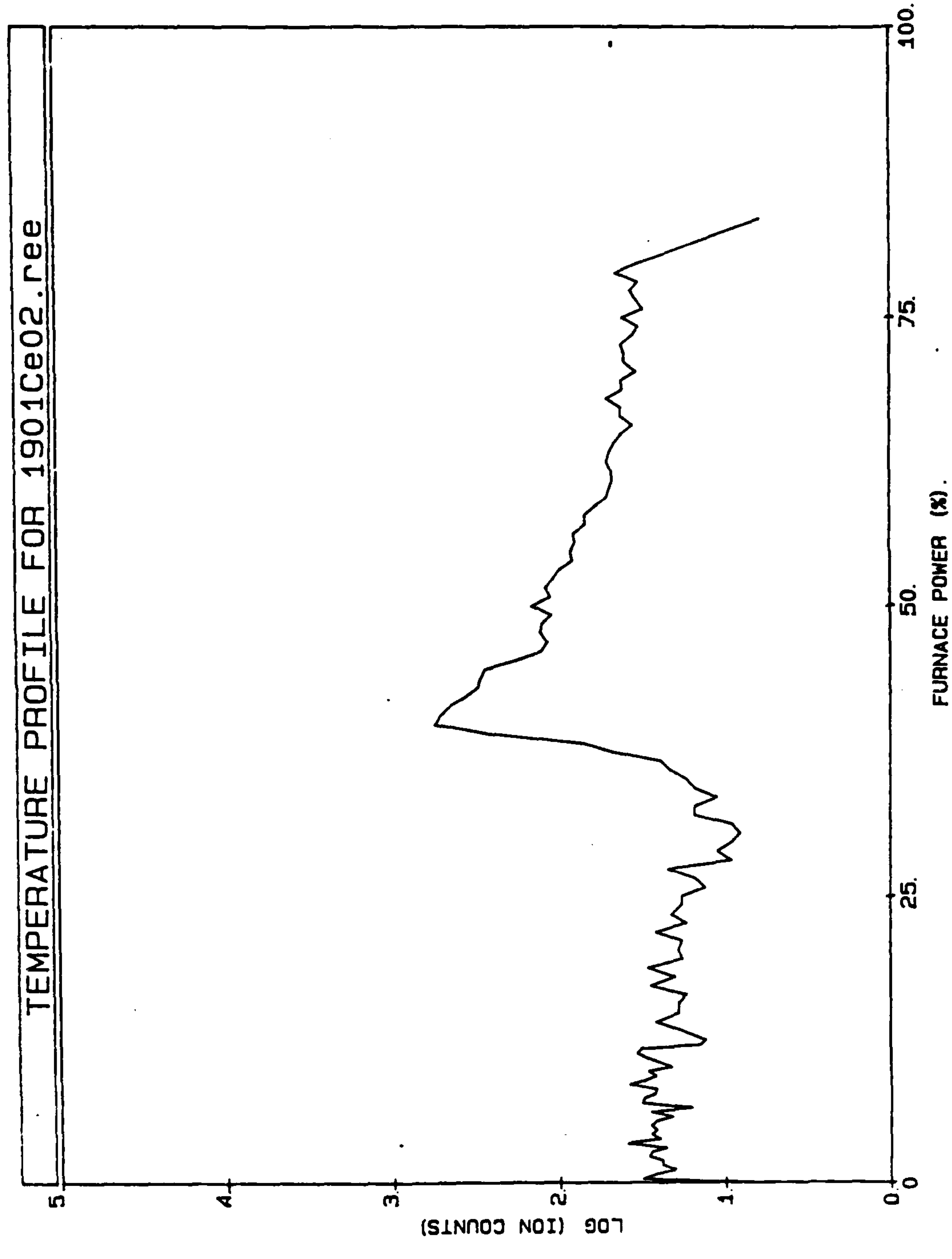

TEMPERATURE PROFILE FOR 1901Dy02.ree
LOG (ION COUNTS)
0.
1.
2.
3.
4.
5
FURNACE POWER (%)
0
25.
50.
75.
100.

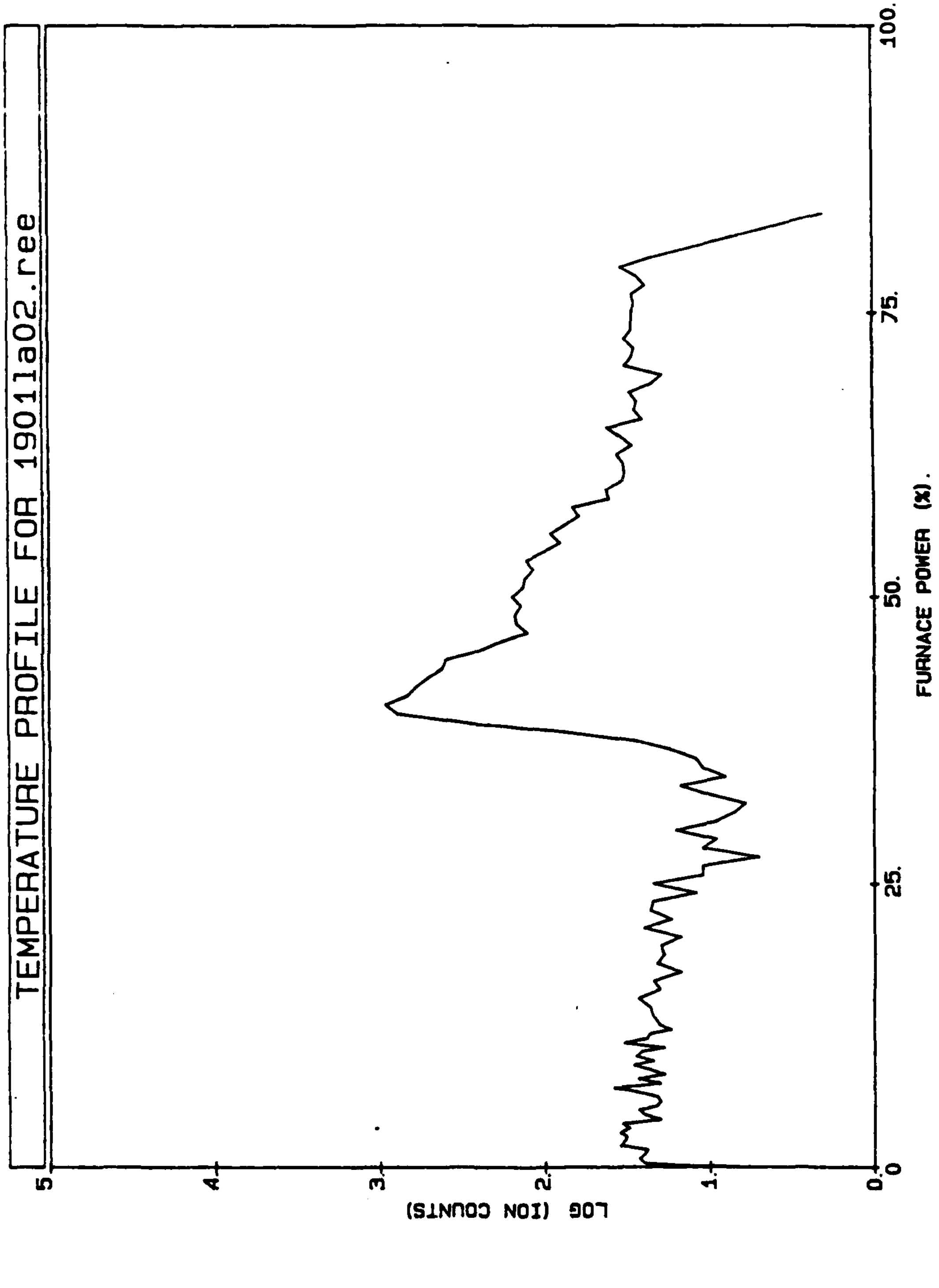

TEMPERATURE PROFILE FOR 1901Gd02.ree
LOG (ION COUNTS)
FURNACE POWER (%)
0.
1.
2.
3.
4.
5.
0
25.
50.
75.
100.


TEMPERATURE PROFILE FOR 1901eu02.ree
LOG (ION COUNTS)
FURNACE POWER (%).
0
1
2
3
4
5
25.
50.
75.
100.


TEMPERATURE PROFILE FOR 1901SmO2.ree
FURNACE POWER (%)
LOG (ION COUNTS)
0
25.
50.
75.
100.
0.0
1.
2.
3.
4.
5


TEMPERATURE PROFILE FOR 1901Nd02.ree
LOG (ION COUNTS)
FURNACE POWER (%)
0
1
2
3
4
5
25.
50.
75.
100.


TEMPERATURE PROFILE FOR 1901Ce02.ree
LOG (ION COUNTS)
0.
1.
2.
3.
4.
5.
FURNACE POWER (%)
0
25.
50.
75.
100.


TEMPERATURE PROFILE FOR 19011a02.ree
LOG (ION COUNTS)
0. 1. 2. 3. 4. 5
FURNACE POWER (%).
0 25. 50. 75. 100.

ADDENDUM

System Changes Since Contract Completion

Software

-Computer controlled selection of gas flows over sample during analysis

-Streamlining of the data collection process. Data is stored for elements and/or isotopes only if they are specified in the **Method File**.

-The structure of the sample analysis has been formalized into two formats a) an unknown sample and b) a uniform matrix.

a) Unknown sample. The time-temperature profile of this sample is stored and then imposed on the standard and the blank. If quantification is desired, the data file must contain a sample, a standard and a blank analysis.

b) Uniform Matrix: This assumes that the sample(s) for analysis are of a known matrix. The first sample develops the time/temperature profile curve and the analysis proceeds as follows: Time/temperature developing sample, standard, blank, sample 1, sample 2, etc.

-Development of quantification software and screen graphics capability. Data is quantified by displaying a plot of the signal vs. furnace temperature for a given atomic mass unit (amu). Integration limits for the plot are set on the screen under curser control. These limits are then applied to all analyses in a single run (sample, standard, blank, etc.) for that amu. Similarly, limits are set for each amu of interest. A printout may be obtained for each amu containing:

-concentration +/- error
-response +/- error
-detection limits +/- error

The "error" above accounts for statistical errors in the data only. All graphics displays may be printed in hard copy.

-Scanning in both the sweep mode and single ion mode is possible.

Critical issues were the amount of data generated and saved, the type of analysis needed, a need for controlling the mixture of gases flowing at different temperatures, and how to analyze data when the time at temperature varied in the sample, standard, and/or blank. A second major development effort for the software and hardware began.

From the crude proof of principle software developed during

the first effort, a user friendly, fully functional analysis product was defined The enhancements include

1) automated data collection in two modes Sample 1, Standard 1, Blank 1, Sample 2, Standard 2, ; Blank 1, Standard 1, Sample 1, Sample 2,

2) a simple built-in editor for the method files,

3) display and/or plotting of the temperature spectra,

4) graphic selection of the temperature region used for analysis,

5) analysis of the data, computing concentration and detection limits,

6) summation of data at 20 AMU's with individually selected half-widths for summation (not all data kept),

7) summation of the data was simplified to a total of 257 bins (numbered -1 for detector stabilization at 0 temperature, and 0 to 255), one for each temperature,

8) single ion mode,

9) valve control for gases,

10) time collection of data for non-furnace applications.

The hardware was productized from the original two board set into a single board that included 4 bits to control valves for gases

HARDWARE

Data Acquisition Board

-The data acquisition and IBM PC/XT/AT interface hardware has been developed into a finished PC board and professionally laid out and assembled

-The electrothermal furnace power controller power supply system has been completely redesigned incorporating a switch mode solid state DC power supply The power output is much smoother and more precise than the initial unit built for the contract.

-Design refinements in the furnace/torch assembly have been implemented, the most significant being a reduction in the amount of tantalum required to construct the furnace body

SOFTWARE CODE

```
dummy method text file for testing
2048  0100                            channels per sweep, integration
time in usec
0020                                  default max sweeps per summation
buffer
0010                                  default min sweeps per temp
0100                                  default max sweeps per temp
0010                                  default # pulses per temp step
0210                                  max temp. stop when this is
exceeded
0100                                  initial sweeps to throw away
0000 0000 0100 0100 0001 0055         start/end temp, min/max sweeps,
temp pulses, max sweeps/sum
0001 0210 0020 0100 0010 0105
-1                                    start amu definitions
0002 0220                             full range of amu's to scan
0002 0002 1000                        starting amu, ending amu,
threshold
0003 0010 0500
0011 0226 0100
```

```
DEFINITION MODULE GSI;

FROM DataBase       IMPORT ShortName,LongName;
FROM PGFiles      IMPORT DataHeaderRCD, DriveTypes;

EXPORT QUALIFIED            Config,
                            ConfigRCD,
                            RCFile,
                            DetermineDacsAndStep,
                            AbortPQ;

TYPE    ConfigRCD =
         RECORD
           NumPrAv        CARDINAL;
           NumPlAv        CARDINAL;
           NumPersAv      CARDINAL;
           NumMCAAv       CARDINAL;
           PrinterNo      CARDINAL;
           PlotterNo      CARDINAL;
           PeriphNo       CARDINAL;
           NumAutoS       CARDINAL;
           AutoNo         CARDINAL;
           RackCode       CARDINAL;
           NumXTubes      CARDINAL;
           NumYTubes      CARDINAL;
           RackY1         CARDINAL;
           RackX1         CARDINAL;
           RackYStep      CARDINAL;
           RackXStep      CARDINAL;
           Height         CARDINAL;
           UpTime         CARDINAL;
           WTime          CARDINAL;
           Drive          DriveTypes;
           MCANo          CARDINAL;
           AutoShut       BOOLEAN;
           DummyA,
           DummyB         BOOLEAN;
           DeadTime       REAL;
           SkipMasses     ARRAY [1..36] OF REAL
         END;

VAR Config                         ConfigRCD;

PROCEDURE DetermineDacsAndStep(VAR HeaderBlock   DataHeaderRCD);
PROCEDURE RCFile;
PROCEDURE AbortPQ;

END GSI
```

```
        page 65,132
        TITLE GET DATA
;       GET DATA   Summation and Storage Program
;
;       Written by J R Hanratty
;       Updated 16-Nov-1986
;       Updated 29-Dec-1986
;       Updated 11-Jan-1987
;       Updated 13-Jan-1987
;
;       Copyright 1986 by James R Hanratty and Geochemical
Services, Inc
;
;       325 Mariposa Drive
;       Camarillo, CA 93010
;       (805) 484-1414
;
;       ALL RIGHTS RESERVED
;
No_Buffers = 14   ; number of buffers reserved to hold data
; old No_Buffers = 21
;
;  hardware definitions
;
smaxt     equu  0b000H+(19*10)+4
stemp     equ   0b000H+(20*10)+4              ; crt locations for
text messages
stimet    equ   0b000H+(21*10)+4
stime     equ   0b000H+(22*10)+4
schan     equ   0b000H+(23*10)+4

port_a1 EQU 3A0H       ; control out
  A1_I_ENB EQU 01H       ; IBM START SCAN
  A1_NEXT  EQU 02H       ; IBM NEXT CHANNEL
  A1_TEMP  EQU 04H       ; STEP TEMP
  A1_RESET EQU 08H       ; RESET
  A1_I_DIS EQU 00H       ; INTERRUPTS DISABLE, 1ST OF 3 BITS
  A1_I_1   EQU 11H       ; INTERRUPTS ENABLE ON EVERY 1
  A1_I_2   EQU 21H       ; INTERRUPTS ENABLE ON EVERY 2
  A1_I_4   EQU 31H       ; INTERRUPTS ENABLE ON EVERY 4
  A1_I_8   EQU 41H       ; INTERRUPTS ENABLE ON EVERY 8
  A1_I_S   EQU 71H       ; INTERRUPTS ENABLE ON EVERY START

port_b1 EQU port_a1 + 1; control in
  B1_FULL  EQU 01H       ; FIFO FULL
  B1_NEAR  EQU 02H       ; FIFO NEAR FULL
  B1_HALF  EQU 04H       ; FIFO HALF FULL
  B1_EMPTY EQU 08H       ; FIFO EMPTY
  B1_ERROR EQU 10H       ; WRITE ERROR

port_c1 EQU port_b1 + 1 ; not used
port_1  EQU port_c1 + 1 ; control word 82h mode 0
```

```
port_a2 EQU port_1   + 1 , lsb
port_b2 EQU port_a2 + 1 , msb
port_c2 EQU port_b2 + 1 , hand shaking
  C2_BUFFER_FULL EQU 02   , THERE IS DATA IN THE BUFFER
port_2  EQU port_c2 + 1 , control word B6H MODE 1
    p2_INTR  EQU 05H       , INTERRUPT on

HEADER EQU 0
 flags          EQU      0   , flags (hi 4 bits) +
                             ,        data length (low 12 bits)
   flags_bad_size      equ  08000h ,  data buffer wrong length
   flags_data_over_run equ  04000h , no free data buffer
   flags_error2        equ  02000h
   flags_error1        equ  01000h

 TEMP           EQU      2      ; TEMP FOR THE CURRENT BUFFER
 START_TIME     EQU      4      , STARTING TIME IN SWEEPS
                                ;    FROM START OF SUMMATION
 ELAPSED_TIME EQU        6      ; ELAPSED TIME IN BUFFER IN SWEEPS
 data_offset    EQU      8      , offset to start of data in buffer

buffer_length_b equu   (511+data_offset+8192) and 0fe00h ; round
up to next
buffer_length_w equ   buffer_length_b/2                  , sector
boundary


        public      summation
SUMIT   SEGMENT   PARA 'CODE'
    ASSUME     CS SUMIT, DS SUMIT, ss a_stack
;   assume     es dummy       , debug code only
,DATA
;
active_flag        dw    0      , status flag for data collection
                                ,    0 -> inactive,
                                ,    1 -> collecting

summation_buffer_ptr dd   0 ; -> summation buffer
data_capture_ptr     dd   0 , -> data capture

buffer_index       dw    0                   ; index into tables: 4 bytes

buffer_chain       DD    No_Buffers    dup (0)

MAX_sweeps_Sum     DW    256   DUP (0)   , max allowed sweeps per
summation

Max_Sweep_Temp     dw    256   dup (0)   , max sweeps per temp
                                         ;   while above threshold or
not
Min_Sweep_Temp     dw    256   dup (0)   , min sweeps per temp,
regardless
```

```
                                                , of the thresholds
Temp_Ramp           dw    256  dup (0)   , # temp pulses per com-
manded step

THRESHOLDS          DD    2048 DUP (0)   , the thresholds

Summation_Flags     DD    2048 dup (0)   , data capture and summation
flags

Commanded_Temp      dw    0                , commanded temperature
new_temp            dw    0                , new temp setting

MIN_SWEEP           DW    0                , min  sweeps/temp
TEMP_INC_PULSES     DW    0                , # temp inc pulses
max_sweep_buffer    dw    0                ; max # sweeps/buffer
,
,the following words must be contiguous
,
CHANNEL_PER_sweep DW      0                , size of data requested
Max_Temp            dw    0                , Commanded stopping Temp
MAX_SWEEP           DW    0                , max  sweeps/temp
first_sector        dw    101              , first sector on drive for
data
disk_drive          dw    2                , the disk drive to use
,
;end of sacred area, caused by the order of copy from the callers
buffer
,

inhibit_temp_inc    dw    0                , data is above threshold
Channel_Threshold dw      0, 0             , exceeded channel and
threshold
Time_at_Temp        dw    0                , elapsed time at tempera-
ture
temp_bumped         dw    0                , the temp has been bumped
CHANNEL_PER_sweep_4 DW     0               , size of data requested*4
starting_sector     dw    -1               , the sector for next write

time_Prompt        db   'xxxxx          Current sweep',0
temp_Prompt        db   'xxxxx          Current temp',0
Max_Temp_prompt    db   'xxxxx          Commanded Maximum temp',0
sameTime_Prompt    db   'xxxxx          Sweeps at current temp',0
Channel_Prompt     db   'xxxxx xxxxx    Channel and threshold
exceeded',0

START     PROC
SUMMATION
      mov         sp, offset a_stack top_stack , setup a stack
      mov         ax, seg a_stack
      mov         ss,ax
      PUSH        CS                 , SETUP DATA SEGMENT
      POP         DS
```

```
        MOV        AH,37          ; SET UP INTERRUPT VECTOR 4Fx
        MOV        AL,4fH         ; CHANGE INTERRUPT REQUEST
        MOV        DX, OFFSET SUMIT.INT_ENTRY
        INT        33

        mov       al,082H         ; set up ports
        mov       dx,port_1
        out       dx,AL

        mov       al,0B6H
        mov       dx,port_2
        out       dx,AL

        mov       al,p2_INTR      ; enable interrupts
        mov       dx,port_2
        out       dx,AL

        mov       al,A1_RESET    ; reset the hardware to start new
        mov       dx,port_a1
        out       dx,AL

        mov       dx,port_a1
        xor       ax,ax          ; clear reset pulse and temp
        out       dx,AL

        mov       dx seg a_stack       ; set up pointers in tables
        add       dx,00fffh       ; cross next 64k boundary
        and       dx,0f000h       ; and fall back to the boundary
        add       dx,2000h        ; reserve two 64k buffers
; old      add       dx,3000h        ; reserve three 64k buffers

exit2
        mov        ax,03100h      ; function code and return status
        INT        33

exit    mov        dx,seg summation
        jmp        exit2
```

```
INT_ENTRY    ,  SOFTWARE INTERRUPT ENTRY
     CMP          AL,0              IDENTIFY THE FUNCTION CODE
     JZ           START_SUM_R     , START
     CMP          AL,2            . DISK READ
     JZ           DISK_READ
     CMP          AL,3            , DISK WRITE
     JZ           DISK_WRITE
     cmp          al,4            , get status
     jz           Get_status      , yes
     cmp          al,5            . terminate and stay resident,
remove our code
     jz           exit
     CMP          AL,1            , STOP
     jnz          summation_exit
     Jmp          STOP_SUM        , YES

START_SUM_R
     JMP          START_SUM

DISK_READ
     CALL         READ_DISK
summation_exit
     IRET                         , UNKNOWN  RETURN

DISK_WRITE  CALL WRITE_DISK
            JMP SUMMATION_EXIT

get_status
     sti
     push         bx
gs_1
     mov          bx,cs active_flag          , collection status
     or           bx,bx
     jnz          gs_1

     pop          bx
     jmp          summation_exit

Disp_Temp:
     push         ax
     push         bx
     push         cx
     push         fx
     push         di
     push         si
     push         ds
     push         es
     mov          ax,stemp
     mov          es,ax
     xor          bx,bx
     mov          ax,cs  Commanded_Temp
```

```
        call        i2bin
        pop         es
        pop         ds
        pop         si
        pop         di
        pop         dx
        pop         cx
        pop         bx
        pop         ax
        ret

Disp_Max_Temp:
        push        ax
        push        bx
        push        cx
        push        dx
        push        di
        push        si
        push        ds
        push        es
        mov         ax,smaxt
        mov         es,ax
        xor         bx,bx
        mov         ax,cs: Max_Temp
        call        i2bin
        pop         es
        pop         ds
        pop         si
        pop         di
        pop         dx
        pop         cx
        pop         bx
        pop         ax
        ret

Disp_Times
        push        ax
        push        bx
        push        cx
        push        dx
        push        di
        push        si
        push        ds
        push        es
       les          bx,cs summation_buffer_ptr
       mov          ax,es start_time[bx]          , and time
       add          ax,es elapsed_time[bx]
       mov          bx,stime
       mov          es,bx
       xor          bx,bx
       call         i2bin
```

```
        mov             ax,cs:Time_At_Temp
        mov             dx,StimeT
        mov             es,dx
        xor             bx,bx
        call            i2bin
         pop            es
         pop            ds
         pop            si
         pop            di
         pop            dx
         pop            cx
         pop            bx
         pop            ax
         ret

Disp_Thresh:
         push           ax
         push           bx
         push           cx
         push           dx
         push           di
         push           si
         push           ds
         push           es
        xor            bx,bx
        mov            ax,cs:Channel_Threshold
        mov            cx,schan
        mov            es,cx
        call           i2bin

        mov            ax,cs:Channel_Threshold+2
        mov            bx,schan
        mov            es,bx
        mov            bx,12
        call           i2bin
         pop            es
         pop            ds
         pop            si
         pop            di
         pop            dx
         pop            cx
         pop            bx
         pop            ax
         ret

mov_text_crt:
        mov             es,di
        xor             di,di
mt2:
        mov             al,cs:[si]          ; get the next character
        or              al,al               ; done?
        jnz             mt1                 ; no
```

```
    ret

mtl: mov        es:[di],al
     inc        si
     add        di,2
     jmp        mt2

I2BIN:    ; INPUTS AX     = INTEGER TO BE DISPLAYED
          ;        ES:BX  = STARTING POSITION IN DISPLAY

          MOV       DL,' '              ; SET THE STARING STRING TO
BLANKS
          MOV       CX,10000            ; GET FIRST DIGIT, TENS OF
THOUSANDS
          CALL      GET_DIGIT

          MOV       CX,1000
          CALL      GET_DIGIT           ; THOUSANDS


          MOV       CX,100
          CALL      GET_DIGIT           ; HUNDREDS

          MOV       CX,10
          CALL      GET_DIGIT           ; TENS

          OR        AL,'0'              ; INSURE UNITS ARE SHOWN AS
INTEGER,
          MOV       ES:[BX],AL          ;   NO LEADING BLANKS
          RET

GET_DIGIT:
          MOV       DH,DL               ; SET DEFAULT CHARACTER
GET_DIGIT_1:
          CMP       CX,AX               ; DO WE HAVE A DIGIT?
          JA        GET_DIGIT_3         ; NO, DONE
          SUB       AX,CX
          OR        DX,'00'             ; SET TO DIGIT
          ADD       DL,1                ; BUMP DIGIT
          JMP       GET_DIGIT_1         ; MORE?
GET_DIGIT_3:
          MOV       ES:[BX],DL          ; OUTPUT THE CHARACTER
          MOv       DL,DH
          ADD       BX,2                ; POINT TO THE NEXT CHARACTER
POSITION
          RET


                              ;
                              ;ax = 1
dp_sum_ptr      EQU 00 ;        summation flags buffer pointer
dp_min_ptr      EQU 04 ;        thresholds ptr
dp_Ramp_ptr     EQU 08 ;        Temp ramp pointer
```

```
dp_min_sweep_p EQU 12 ,        min sweeps/temp
dp_max_sweep_p EQU 16 ,        max sweeps/temp
dp_max_ptr     EQU 20 ,        max sweeps per summation ptr
dp_channels    EQU 24 ,        channels/sweep
dp_Max_temp    EQU 26 ,        max commanded temp
dp_Throw_Away  equ 28 ;        # sweeps to throw away at 0 temp
                      ,
                      ;  es  sec pointer
                      ,
START_SUM:
      sti
      cld            , all transfers in the forward direction
      push     bz             ; save context
      push     cx
      push     dx
      push     si
      push     ds
      push     es
      push     di

      push     es             , save these for now
      push     di

      mov      ax,cs
      mov      ds,ax          ; point to the proper segment
      mov      ah,37          , hardware interrupt setup
      mov      al,08h+3       , vector to our summation code
      mov      dx, offset sumit:hard_int , our entry
      int      33

      mov      commanded_Temp,0   , start temp ramp from 0

      pop      di             , get pointer to our data
      pop      es             , and segment info

      push     di             , save for later
      mov      bx,di          ,copy
,
;copy control variables   Summation_flags, Thresholds,
,                         Temp_Ramp,
;                         min_sweep_temp, max_sweep_temp,
;                         Max_sweeps_sum, channel_per_sweep,
;                         Max_temp, throw_away
;
      lea      si,es:dp_channels[di]        , starting location
      mov      di, offset sumit:channel_per_sweep
      mov      cx,10                         , 5 words = 10 bytes

      mov      ax,es
      mov      ds,ax
      mov      dx,cs
      mov      es,dx
```

```
        rep movsb                               ; move all 2 words

;
;copy summation flags in
;
        mov     di,bx                           ; get parameter index
        mov     ds,ax
        lds     si,ds:dp_sum_ptr[di]    ; target address
        mov     di, offset sumit:Summation_flags ; source address
        mov     cx, size Summation_flags        ; length of array
        rep movsb                               ; move the array

;
;copy max sweeps/sumation
;
        mov     di,bx                           ; index to parameters
        mov     ds,ax
        lds     si,ds:dp_max_ptr[di]            ; source address
        mov     di,offset sumit.max_sweeps_sum ; destination
        mov     cx, size max_sweeps_sum  ; length
        rep movsb                               ; move the array

;
;copy thresholds
;
        mov     di,bx                           ; index to parameters
        mov     ds,ax
        lds     si,ds:dp_min_ptr[di]            ; source address
        mov     di,offset sumit.thresholds      ; destination address
        mov     cx, size thresholds             ; length
        rep movsb                               ; move the array


;
;copy temp ramp
;
        mov     di,bx                           ; index to parameters
        mov     ds,ax
        lds     si,ds:dp_ramp_ptr[di]           ; source address
        mov     di,offset sumit.Temp_Ramp       ; destination address
        mov     cx, size Temp_ramp              ; length
        rep movsb                               ; move the array


;
;copy Min Sweeps per temp
;
        mov     di,bx                           ; index to parameters
        mov     ds,ax
        lds     si,ds:dp_min_sweep_p[di]        ; source address
        mov     di,offset sumit.Min_sweep_Temp ; destination
address
        mov     cx, size Min_Sweep_Temp         ; length
        rep movsb                               ; move the array


;
```

```
,copy Max Sweeps per temp
;
      mov       di,bx                          ; index to parameters
      mov       ds,ax
      lds       si,ds:dp_max_sweep_p[di]       ; source address
      mov       di,offset sumit.Max_sweep_Temp ; destination
address
      mov       cx, size Max_Sweep_Temp        ; length
      rep movsb                                ; move the array

      mov       es,ax                          ; es -> parameters

      mov       ax,cs:Max_Sweep                ; set max and mins for
1st sweep
      mov       cs:min_sweep,ax
      mov       cs:Max_sweep_Buffer,ax         ; and sum them all up
      mov       cs:Temp_Inc_Pulses,0           ; inhibit temp inc for
first step

      mov       ax,seg a_stack         ; set up pointers in tables
      add       ax,00fffh       ; cross next 64k boundary
      and       ax,0f000h       ; and fall back to the boundary

      mov       bx,cs
      mov       ds,bx
      mov       es,ax           ; use the new segment address of the
buffers

      mov       buffer_index,0   ; point to the first buffer index
      mov       word ptr summation_buffer_ptr,BUFFER_LENGTH_B ;
summation -> DUMMY
      mov       word ptr summation_buffer_ptr+2,ax
      mov       word ptr data_capture_ptr,0 ; data capture -> 1ST
REAL
      mov       word ptr data_capture_ptr+2,ax

      push      ds
      push      ax

; old    mov       dx,3           ; show three buffers to clear
      mov       dx,2           ; show two buffers to clear
      mov       ds,ax

LL4:  mov       cx,08000h      ; length of each buffer in words
      mov       ax,0           ; data value for start
      mov       bx,0           ; initial index

LL5:  mov       ds:[bx],ax
      add       bx,2
      loop      LL5

      mov       ax,ds           ; get and bump data seg
```

```
        add     ax,1000h
        mov     ds,ax
        dec     dx
        jnz     LL4

        pop     ax
        pop     ds

        MOV     word ptr es:(buffer_length_b+TEMP),-1
                                ; MARK THE CURRENT TEMP
                                ;    OF DUMMY SUMMATION AS -1

        mov     word ptr es:flags,0
        mov     word ptr es:temp,0
        mov     word ptr es:start_time,0
        mov     word ptr es:elapsed_time,0

        mov     word ptr es:flags+buffer_length_b,0
        mov     word ptr es:start_time+buffer_length_b,0
        mov     word ptr es:elapsed_time+buffer_length_b,0

        mov     bx,offset buffer_chain
        call    set_pointers
        add     ax,1000h
        call    set_pointers
;       add     ax,1000h
;       call    set_pointers

        mov     ax,CHANNEL_PER_sweep
        add     ax,ax   ; * 4
        add     ax,ax
        sub     ax,10 ; remove a few sweeps just in case
        mov     CHANNEL_PER_sweep_4,ax

        mov     ax,first_sector                 ; init disk xfer
address
        inc     ax
        mov     starting_sector,ax              ; the first is really
for header

        pop     di


        mov     al,082H         ; set up ports
        mov     dx,port_1
        out     dx,AL

        mov     al,0B6H
        mov     dx,port_2
        out     dx,AL

        mov     al,p2_INTR      ; enable interrupts
```

```
        mov     dx,port_2
        out     dx,AL

        mov     al,A1_RESET     , reset the hardware to start new
        mov     dx,port_al
        out     dx,AL

        xor     ax,ax           ; remove the reset signal
        out     dx,al

x:      mov     dx,port_c2      , clear any data that's left
        in      al,dx
        and     al,C2_Buffer_Full
        jz      a
        dec     dx
        in      al,dx          , msb
        dec     dx
        in      al,dx
        jmp     x
a:

        mov     dx,port_al
        mov     al,A1_I_s      , clear reset pulse and arm interrupts
        out     dx,AL

        xor     ax,ax           , o -> interrupt mask reg of 8259
        mov     dx,21h
        out     dx,al

       mov     di,stemp                        , label the data area
       mov     si,OFFSET temp_prompt           ; current temp prompt
       call    mov_text_crt

       mov     di,stime
       mov     si,OFFSET time_prompt           ; current temp prompt
       call    mov_text_crt

       mov     di,stimet
       mov     si,OFFSET sametime_prompt       , current temp prompt
       call    mov_text_crt

       mov     di,schan
       mov     si,OFFSET channel_prompt        , current temp prompt
       call    mov_text_crt

       mov     di,smaxt
       mov     si,OFFSET max_temp_prompt       , current temp prompt
       call    mov_text_crt

       xor     ax,ax                           , zero initial displays
       mov     cs. Commanded_Temp,ax
       mov     cs  Channel_Threshold+0,ax
```

```
    mov     cs:Channel_Threshold+2,ax
    mov     cs:Time_At_Temp,ax

    call    Disp_Thresh
    call    Disp_Temp
    call    Disp_Times
    call    Disp_Max_Temp

    mov     cs:active_Flag,1    ; show active

    pop     di
    pop     es
    pop     ds
    pop     si          ;restore context
    pop     dx
    pop     cx
    pop     bx

    jmp     summation_exit

set_pointers:
    mov     cx,7
    xor     dx,dx
17  mov     cs:[bx],dx
    mov     cs:2[bx],ax
    add     bx,4
    add     dx,buffer_length_b
    loop    17
    ret


STOP_SUM:
    int     08h+3               ; fake data ready to collect any
data
    mov     ax,al_reset         ; reset temp and turn interrupts
off
    mov     dx,port_a1
    out     dx,al
    xor     ax,ax               ; turn off interrupts
    out     dx,al
    call    flush_to_disk

    mov     cs:active_Flag,0    ; show inactive

    jmp     summation_exit

hard_int:
    cld             ; all transfers in + direction
    push    di
    push    si                  ; save context
    push    ds
    push    dx
```

```
        push    ax
        push    bx
        push    es
        push    cx

        lds     bx,cs:data_capture_ptr
        les     di,cs:summation_buffer_ptr

        xor     ax,ax       ; turn off interrupts
        mov     dx,port_a1
        out     dx,al

        mov     al,20h      ; send eoi to 8259
        out     20h,al
        sti                 ;allow other interrupts to occur

more_data
        mov     si,ds:flags[bx] ; index into data
more_data_2:
        mov     dx,port_c2              ; test for errors and data
        in      al,dx
        test    al,c2_buffer_full       ; is there data?
        jz      more_data_2             ;; jrh debug loop until done
;       jz      empty                   ; no, so why the interrupt?

        dec     dx                      ; port_b2  to get msb
        in      al,dx
        mov     ah,al                   ; put in msb of result
        dec     dx                      ; get lsb form port_a2
        in      al,dx

        or      ax,ax                   ; if 2 ms bits on, then new
frame
        js      more_data_1             ; new frame

cont:
        mov     ds:data_offset[bx][si],ax ; store the data
        mov     word ptr ds:data_offset+2[bx][si],0
        cmp     WORD PTR cs:thresholds[si],ax   ; is this too high?
;       jns     cont_1                  ; no, below threshold, get it
        jae     cont_1                  ; no, below threshold, get it
        cmp     cs:inhibit_temp_inc,1   ; all ready flagged?
        je      cont_1                  ; yes

        mov     cs:inhibit_temp_inc,1   ; inhibit possible temp inc

        mov     word ptr cs:Channel_Threshold+0,ax      ; jrh debug
value exceeding thresholds
        mov     word ptr cs:Channel_Threshold+2,si      ; jrh debug
and the index too
        sar     word ptr cs:Channel_Threshold+2,1
        sar     word ptr cs:Channel_Threshold+2,1
```

```
        call    disp_Thresh

cont_1:
        add     si,4                    ; bump data pointer
        jmp     more_data_2
                                        ; not new, continue summation
more_data_1:
        and     ax,03fffh               ; clear two top bits from temp

        or      si,si                   ; if index = zero, continue
summation
        jz      more_data_3             ; no data, begin collection

        cmp     cs:channel_per_sweep_4,si ; continue collecting
data?
        jg      more_data_2             ; yes, we found a fast sweep
break

        call    sum_new                 ; test and sum or fulsh as
needed
        mov     cs:inhibit_temp_inc,0   ; remove inhibit possible
temp inc
        jnc     more_data               ; and begin looking for data
        jmp     empty_and_done

more_data_3:
        mov     ds:temp[bx],ax          ; show the temp
        jmp     more_data_2             ; and start collecting the data

empty:
        mov     ds:flags[bx],si  ; save pointer

        mov     dx,port_a1
        mov     al,A1_I_s       ; arm interrupts
        out     dx,AL

empty_and_done:

        pop     cx
        pop     es
        pop     bx
        pop     ax
        pop     dx
        pop     ds
        pop     si
        pop     di
        jmp     summation_exit


;
; subroutines
;
```

```
new_temperature:
      mov       cs:Time_at_Temp,0          ; start timing again
      mov       cs:temp_bumped,0           ; show new start
new_temperature_2
      mov       ax,cs:new_temp             ; save the new temp for data
summation
      mov       ds:temp[bx],ax
      call      disp_Times
      clc
      ret

sum_new:  ;  if summation buffer and data_capture are the same,
sum it up
          ;  if not same, send summation, and start new summation
with data_capture
      mov       ds:flags[bx],si  ; save the index into the data
buffer
      mov       cs:new_temp,ax             ; save new temp
      les       di,cs:summation_buffer_ptr
      test      es:flags[di],3fffh             ; data in summation
buffer?
      jz        no_data                    ; no, use data as is, no
summing
      mov       ax,ds:temp[bx]
      cmp       es:temp[di],ax             ; if temp matches
      jz        same_temp                  ; continue summation
      cmp       cs:max_temp,ax             ; are we now done?
      jg        no_data                    ; no, continue
      call      flush
      call      flush_to_disk              ; yes we are done, finish
and exit
      mov       al,al_Reset                ; kill temp and all
      mov       dx,port_al
      out       dx,al
      xor       ax,ax
      out       dx,al

      mov       cs:active_Flag,0   ; show inactive

      stc                                  ; show done
      ret                                  ; return

no_data:
      call      flush                    ; otherwise, flush sum buffer
      jmp       new_temperature          ; and start with a new sum

same_temp
      inc       word ptr cs:time_at_temp         ; time at this temp
      call      disp_Times

      mov       ax,es:elapsed_time[di]      ; insure in range of
summation buffer limits
```

```
        cmp       ax,WORD PTR cs.max_sweep_buffer
;       jns        flush_it              ; enough data summed, start
new sum
        jae       flush_it              ; enough data summed, start new
sum
        mov       ax,cs.temp_bumped       ;  have we bumped this temp?
        or        ax,ax
        jnz       same_temp_4
        mov       ax,cs.time_at_temp      ; too long at temp?
        cmp       ax,cs.max_sweep         ; exceeding max thresholds?
;       js         same_temp_i           ; no, more tests follow
        jb        same_temp_1           ; no, more tests follow
same_temp_2:
        mov       cs:temp_bumped,1        ; show we've bumped temp
        call      bump_temp
        jmp       same_temp_4           ; continue summation

same_temp_i
        cmp       ax,cs:min_sweep         ; have we been here long
enough?
;       js         same_temp_4           ; no, we must wait more
        jb        same_temp_4           ; no, we must wait more
        test      cs:inhibit_temp_inc,0ffffh ; can we inc temp?
        jz        same_temp_2           ; yes, so do it and continue
same_temp_4
        mov       ax,ds.flags[bx]       ; and length match
        cmp       ax,es:flags[di]               ; ?
        jnz       flush_it              ; data -> send it

sum_it_up
        mov       ax,cs:new_temp           ; save new temp in slot for
next temp
        mov       ds:temp[bx],ax
        inc       word ptr es.elapsed_time[di]          ; time in this
summation
        mov       cx,ds:flags[bx]                         ; set counter
        mov       word ptr ds:flags[bx],0       ; start next data
capture fresh
        sar       cx,1
        sar       cx,1
        mov       si,data_offset        ; starting address of data
        add       si,bx

        push      di                    ; save the summation buffer
address
        add       di,data_offset

add_i
        mov       ax,ds [si]            ; get lsw
        add       es:[di],ax            ; form lower sum
        jnc       add_2
        inc       word ptr es.2[di]       ; for carry, inc msw
```

```
add_2:
      add       si,4                    ; bump pointers
      add       di,4
      loop      add_1                   ; loop counter

      pop       di
      clc
      ret

flush_it:
      call      flush                   ; output the summation buffer
      jmp       new_temperature_2       ; and start anew

bump_temp:
      push      bx
      mov       bx,cs:Commanded_Temp    ; get commaned temp
      add       bx,bx                   ; form word offset
      mov       ax,cs:temp_ramp[bx]     ; get # pulses for next step
      mov       cx,cs:Temp_inc_pulses   ; # pulses this step
      mov       cs:Temp_inc_pulses,ax   ; and set for next step
      add       cs:Commanded_Temp,cx    ; form new temp
      add       bx,cx                   ; and index into the tables
      add       bx,cx
      mov       ax,cs:Min_Sweep_temp[bx] ; get new max and mins
      mov       cs:min_sweep,ax
      mov       ax,cs:Max_Sweep_temp[bx]
      mov       cs:max_sweep,ax
      mov       ax,cs:Max_Sweeps_Sum[bx] ; max sums/buffer
      mov       cs:Max_Sweep_Buffer,ax
      pop       bx
      mov       dx,port_a1              ; control port
      mov       al,a1_temp              ; leave interrupts alone,
                                        ;  and work with temp
      mov       ah,a1_temp

      or        cx,cx                   ; if count = 0, 1st inc = throw
away
      jnz       bump_temp_1
      mov       cs:Time_at_temp,0
      mov       cs:Temp_bumped,0
      jmp       bump_temp_4
bump_temp_1:
      out       dx,al
      xor       al,ah                   ; set hi
      out       dx,al
      xor       al,ah
      loop      bump_temp_1
bump_temp_4
      call    disp_Temp
      clc
      ret
```

```
flush
      lds        bx,cs data_capture_ptr
      les        di,cs:summation_buffer_ptr

      mov        ax,es:elapsed_time[di]      ; update time stamp
      add        ax,es:start_time[di]
      mov        ds:start_time[bx],ax
      mov        word ptr ds:elapsed_time[bx],1       ; start elapsed
time off

      sar        word ptr es:flags[di],1               ; convert byte
offset to count
      sar        word ptr es:flags[di],1

      mov        word ptr cs:summation_buffer_ptr+0,bx   ; dc -> sb
      mov        word ptr cs:summation_buffer_ptr+2,ds

      mov        bx,cs:buffer_index          ; get next dc buffer
      add        bx,4
      cmp        bx,(4*No_Buffers)                   ; wrap around?
      jne        flush_1
      xor        bx,bx                       ; yes, start again
flush_1
      mov        cs:buffer_index,bx          ; save index for next
time
      lds        bx,cs buffer_chain[bx]
      mov        word ptr cs:data_capture_ptr+0,bx ; and the dc ->
too
      mov        word ptr cs:data_capture_ptr+2,ds
      mov        word ptr ds:flags[bx],0 ; start data capture fresh

      cmp        di,(6*buffer_length_b)      ; do we need to write?
      jnz        flush_2                     ; <> 0 -> no

flush_3
      push       ax
      push       bx
      push       cx
      push       dx
      push       ds

      mov        cx,di                       ; transfer length in
sectors
      add        cx,buffer_length_b          ;  in bytes to
      sar        cx,1                        ;  words
      mov        cl,ch                       ;  and to sectors
      and        cx,07fh

      mov        dx,cs starting_sector       ; starting sector
      add        cs:starting_sector,cx       ; update for next
transfer
```

```
        mov     bx,es                           ; segment address
        mov     ds,bx

        XOR     BX,BX                           ; SEGMENT OFFSET

        call    write_disk

        pop     ds
        pop     dx
        pop     cx
        pop     bx
        pop     ax
flush_2
        clc
        ret

flush_to_disk:
        call    flush                           ; output current
summation
        mov     word ptr ds:elapsed_time[bx],0
        call    flush                           ; second with 0
et
        cmp     word ptr cs:summation_buffer_ptr,0 ; did we do a
write?
        jnz     flush_3                         ; no, do it now
        clc
        ret

READ_DISK:
        mov     ax,cs:Disk_drive                ; drive #
        int     37                              ; do disk write

        jnc     RD_4
        nop                                     ; no error checking
RD_4:
        pop     ax                              ; remove the garbage
left by dos
        RET

WRITE_DISK:
        mov     ax,cs:Disk_drive                ; drive #
        int     38                              ; do disk write

        jnc     WD_4
        nop                                     ; no error checking
WD_4
        pop     ax                              ; remove the garbage
left by dos
        RET

END_SUMMATION:
```

```
START     ENDP
SUMIT     ENDS


a_stack   segment    PARA stack 'STACK'
          dw      50 dup (0)
top_stack dw      0
a_stack   ends

          END          SUMMATION
```

```
(* Copyright 1986 Michael Rogers and GeoChemical Inc *)
(* all rights reserved *)
(* $C-*)
MODULE DATAREAD,
  FROM SYSTEM
    IMPORT BYTE, WORD, ADDRESS, ADR, SIZE, TSIZE, CODE,
    INBYTE, OUTBYTE, INWORD, OUTWORD,
  FROM System
    IMPORT Terminate, Status,
    ProcessPtr, ProcessDescriptor, curProcess;
  FROM MemoryOperations
    IMPORT FillChar, Move, Hi, Lo, Swap, And, Not, Or, Xor, Shr,
    MemGet, MemWGet, PortGet, PortWGet, MemSet, MemWSet, PortSet,
    PortWSet, Ptr, Ofs, Seg, Cseg, Dseg, Sseg, MemAvail,
  FROM FloatingUtilities IMPORT Frac, Int, Round, Float, Trunc,
  FROM ScreenHandler
    IMPORT ClrEol, ClrScr, DelLine, InsLine, GotoXY, WhereX,
WhereY,
    CrtInit, CrtExit, LowVideo, NormVideo, HighVideo, SetAt-
tribute,
    GetAttribute, normalAtt, boldAtt, reverseAtt, underlineAtt,
    blinkAtt, boldUnderlineAtt, blinkUnderlineAtt, boldBlinkAtt,
    reverseBlinkAtt, boldUnderlineBlinkAtt,
  FROM TFileIO
    IMPORT Append, AssignFile, Close, Erase, Flush, Rename,
    Reset, Rewrite, Truncate, Eof,
  FROM TRealIO IMPORT ReadReal, WriteReal;
  FROM TTextIO
    IMPORT ReadInt, ReadCard, ReadChar, ReadString, ReadLn,
ReadBuffer,
    WriteInt, WriteCard, WriteChar, WriteString, WriteBool,
WriteLn,
    Eoln, SeekEof, SeekEoln;
  FROM TBinaryIO
    IMPORT Read, BlockRead, Write, BlockWrite, BlockRWResult,
    FilePos, FileSize, Seek, LongFileSize, LongFilePosition,
LongSeek,
  FROM TKernelIO
    IMPORT File, FileType, OptionMode,
    StatusProc, ReadProc, WriteProc, ErrorProc,
    stdinout, input, output, con, trm, kbd, lst, aux, usr,
    conStPtr, conInPtr, auxInPtr, usrInPtr, conOutPtr, lstOutPtr,
    auxOutPtr, usrOutPtr, errorPtr, IOresult, KeyPressed,
IOBuffer,
    IOCheck, DeviceCheck, CtrlC, InputFileBuffer,  OutputFileBuf-
fer;
  FROM TDOS IMPORT MsDos, Intr, RegPack,

  CONST
    maxint              = 32767;
    Seci       - 0a000H,
    DiskDrive           = 2;
```

```
    NMaxSweeps = 30000,
    Solid = 0FFFFH,

  TYPE
    ShortString = ARRAY [0..25] OF CHAR;
    OptionsAvailable = (FirstSet , SecondSet , ThirdSet );
    IDType = ARRAY [1  5] OF CARDINAL;
    PointerToWord = POINTER TO INTEGER;
    string80 = ARRAY [0..80-1] OF CHAR;
    doubleInteger = ARRAY [0..1] OF INTEGER;

  VAR
    AMUM,
    AMUI,
    realcounts,
    sum,
    I,
    FirstAmu,
    LastAmu              : REAL;
    throwAway,
    numberofprofiles,
    MAXTEMP,
    StartingAmu,
    EndingAMU,
    xtemp,
    elapsedTime,
    rsize,
    counter,
    Difference,
    X,
    j,
    i                    : INTEGER;
    diskBlock            : CARDINAL;
    comma,
    achr                 : CHAR;
    Done,
    done                 : BOOLEAN;
    result               : RECORD
                             ax,
                             bx,
                             cx,
                             dx,
                             bp,
                             si,
                             di,
                             ds,
                             es,
                             flags     : INTEGER;
                           END;

   DriverParameterBlock : RECORD
                             SummationPtr       : POINTER TO
```

```
doubleInteger;
                                ThresholdsPtr      : POINTER TO
doubleInteger;
                                TempRampPtr        : POINTER TO
INTEGER;
                                TempMinPtr         : POINTER TO
INTEGER;
                                TempMaxPtr         : POINTER TO
INTEGER;
                                MaxSweepsPtr       : POINTER TO
INTEGER;
                                ChannelsPerSweep   : INTEGER;
                                MaxTemp            : INTEGER;
                                ThrowAwayNum       : INTEGER;
                                FirstSectorNum     : CARDINAL;
                                DiskDriveNum       : INTEGER;
                                MethodFileName     : string80;
                                SAMU               : REAL;
                                EAMU               : REAL;
(* SPARES ARE USED ONLY TO PROVIDE SPACE TO RECEIVE DATA TRANS-
FERRED WHEN A
SINGLE SECTOR IS READ DIRECTLY FROM THE DISK *)
                                SPARES             : ARRAY [1..(512--
130)] OF BYTE;
                                END;

    dataRecord          : RECORD
                          size        : INTEGER;
                          temp        : INTEGER;
                          stime       : INTEGER;
                          etime       : INTEGER;
                          dataA       : ARRAY [0..4095] OF INTEGER;
                          spares      : ARRAY [0..512] OF INTEGER;
                          END;

    firstetc              ShortString;
    outFileName         : string80;
    Y                   : ARRAY [0..5] OF ShortString;
    dataFile            : File;
    halfwidth,
    lower,
    upper,
    Channelofinterest : ARRAY [0..5] OF INTEGER;
    realZero,
    realSum             : ARRAY [0..2048] OF REAL;
    realTemp            : ARRAY [0..256],[0..5] OF INTEGER;
    realCounts          : ARRAY [0..256],[0..5] OF REAL;

  PROCEDURE sumToReals;

    VAR
```

```
      i: INTEGER;
  BEGIN
    FOR i := 0 TO rsize-1 DO
      realSum[i] := Float(dataRecord.dataA[i*2])+Float(dataRecor-
d dataA[i*2+1])*65536 0+realSum[i],
    END,
  END sumToReals;


  PROCEDURE ReadDiskSectors ( VAR StartingSector    . CARDINAL;
                                  NumberOfSectors   : INTEGER;
                                  DataRecord        · Pointer-
ToWord),
  BEGIN
    WITH result DO
      cx := NumberOfSectors;
      dx := StartingSector;
      INC(StartingSector, cx);
      ds := Seg(ADR(DataRecord^)),
      bx  = Ofs(ADR(DataRecord^));
      ax := 2; (*read*)
      Intr(04fH, result);
    END;
  END ReadDiskSectors,

  PROCEDURE ReadDiskHeader;
  BEGIN
    diskBlock := Sec1,
    ReadDiskSectors( diskBlock, 1, ADR(DriverParameterBlock));
  END ReadDiskHeader;

  PROCEDURE readDisk;
  BEGIN
    ReadDiskSectors (diskBlock,
                        17, (*2048*4+512 / 512  # sectors*)
                        ADR(dataRecord));
  END readDisk,
PROCEDURE FirstEtc;
BEGIN
    Y[1] := 'first';
    Y[2]  = 'second';
    Y[3] := 'third';
    Y[4]  = 'fourth';
    Y[5] := 'fifth';
    firstetc := Y[i];
END FirstEtc;

PROCEDURE WriteDataToDiskFile,
BEGIN
  FOR i .= 1 TO numberofprofiles DO
    FirstEtc,
    WriteString(stdinout, '             Enter file for ',0);
```

```
    WriteString(stdinout, firstetc,0),
    WriteString(stdinout, ' raw temperature profile ', 0),
    ReadBuffer(on);
    ReadString(stdinout, outFileName),
    ReadLn(stdinout);
    ReadBuffer(off),
    AssignFile(dataFile, outFileName, text);
    Rewrite(dataFile, 0),
    sum := Float(0),
    WriteReal(dataFile, realZero[Channelofinterest[i]], 10, 4);
    WriteLn(dataFile),
    WriteInt(dataFile, (counter-1), 6),
    WriteLn(dataFile),
    FOR j := 1 TO counter-1 DO
      WriteInt(dataFile, realTemp[j][i], 4),
      WriteReal(dataFile, realCounts[j][i], 8, 0);
      WriteLn(dataFile);
    END;
    Close(dataFile);
  END;
END WriteDataToDiskFile;

PROCEDURE ChannelOfInterest,

BEGIN
   WITH DriverParameterBlock DO
      FirstAmu := DriverParameterBlock.SAMU;
      LastAmu  := DriverParameterBlock.EAMU;
      WriteLn(stdinout);
      WriteString(stdinout, '                              Starting
Mass = ',0);WriteReal(stdinout,FirstAmu,10,5);
      WriteLn(stdinout),
      WriteString(stdinout, '                                Ending
Mass = ',0);WriteReal(stdinout,LastAmu,10,5);
        AMUM := FLOAT(ChannelsPerSweep-1)/(LastAmu-FirstAmu),
        AMUI := 1.0-(FirstAmu*AMUM);
    END;
  WriteLn(stdinout);
  WriteLn(stdinout),
  WriteString(stdinout, '              You may create up to 5 Temp
profiles at once ',0),
  WriteLn(stdinout),
  WriteString(stdinout, '
  Your Choice :',0),
  ReadBuffer(on),
  ReadInt(stdinout, numberofprofiles),
  ReadLn(stdinout);
  ReadBuffer(off),
  WriteLn(stdinout),
  WriteString(stdinout, '              You may choose the channel
and halfwidth of each profile',0),
  WriteLn(stdinout),
```

```
  FOR i := 1 TO numberofprofiles DO
    FirstEtc,
    WriteString(stdinout, '                   Enter ',0);
    WriteString(stdinout,firstetc,0),
    WriteString(stdinout, ' center channel and profile halfwidth
.', 0);
    ReadBuffer(on);
    ReadInt(stdinout, Channelofinterest[i]),
    ReadInt(stdinout, halfwidth[i]),
    ReadLn(stdinout),
    ReadBuffer(off),
  END;
  Determinehalfwidth,
  WriteLn(stdinout),
END       ChannelOfInterest;

PROCEDURE Determinehalfwidth;
BEGIN
  FOR i := 1 TO numberofprofiles DO
    iower[i] := Channelofinterest[i] - halfwidth[i];
    upper[i] := Channelofinterest[i] + halfwidth[i];
  END,
END Determinehalfwidth;


PROCEDURE ReadDataAndZeroSumIt,
BEGIN
  FOR i  = 0 TO 2047 DO
    realSum[i]  := 0.0,
    realZero[i] := 0 0,
  END,
  ReadDiskHeader,     (* put data in header of file *)
  throwAway := DriverParameterBlock ThrowAwayNum;
  rsize     := DriverParameterBlock ChannelsPerSweep,
  MAXTEMP   := DriverParameterBlock MaxTemp,
  ClrScr;
  WriteLn(stdinout),
  WriteLn(stdinout);
  WriteString(stdinout,'                 Maximum Temperature for
analysis .    ',0),
  WriteInt(stdinout,MAXTEMP,5);
  WriteLn(stdinout),
  WritgString(stdinout,'                 Number of channels per
sweep          ',0),
  WriteInt(stdinout, rsize,5),
  WriteLn(stdinout),
  done := FALSE,
  WITH result DO
    WITH dataRecord DO
      elapsedTime  = 0,
      REPEAT
        readDisk,
```

```
          INC(elapsedTime, etime);
        UNTIL  ((elapsedTime >= throwAway) OR (etime = 0) OR (size
= 0));
        WriteString(stdinout,'                  Number of throwaway
sweeps read   ',0);
        WriteInt(stdinout, elapsedTime,5);
        WriteLn(stdinout);
        elapsedTime := 0;
        REPEAT
          IF size = rsize THEN
            sumToReals;
            INC(elapsedTime, etime);
          END;
          readDisk;
        UNTIL  ((etime = 0) OR (size = 0) OR (temp <> 0));
        WriteString(stdinout,'                  Number of zerocorrec-
tion sweeps read ',0);
        WriteInt(stdinout, elapsedTime, 5);
        WriteLn(stdinout);
        FOR i := 0 TO 2047 DO
          realZero[i] := realSum[i]/Float(elapsedTime);
          realSum[i] := 0.0;
        END;
        elapsedTime := 0;
        counter := 1;
        ChannelOfInterest;
        REPEAT
          REPEAT
            IF (elapsedTime=0) THEN
              xtemp := dataRecord.temp;
            END;
            IF size = rsize THEN
              sumToReals;
              INC(elapsedTime, etime);
            END;
            readDisk;
          UNTIL ((temp<>xtemp) OR (etime=0) OR (size=0));
          FOR i := 1 TO numberofprofiles DO
            realcounts := 0.0;
            FOR j := lower[i] TO upper[i] DO
              realcounts := realcounts+(realSum[j]/Float(elapsed-
Time));
            END;
            realTemp[counter][i] := xtemp;
            realCounts[counter][i] := realcounts;
            FOR j := lower[i] TO upper[i] DO
              realSum[j] := 0.0;
            END;
          END;
          counter := counter+1;
          elapsedTime := 0;
          IF (xtemp>=MAXTEMP) THEN
```

```
          done   = TRUE
        END,
      UNTIL done,
      WriteString(stdinout,'        "        Finished reading data
    ',0),
      WriteLn(stdinout);
      WriteDataToDiskFile,
    END,
  END;
END ReadDataAndZeroSumIt;

BEGIN (*mainline*)
  AMUI  = 0 0;
  AMUM  := 1.0,

  REPEAT
    ClrScr,
    WriteLn(stdinout);
    WriteLn(stdinout),
    WriteString(stdinout, '                                   GSI DMA
SOFTWARE', 0),                    WriteLn(stdinout);
    WriteString(stdinout, '                        Copyright 1986 Geochem-
ical Services, Inc ', 0),  WriteLn(stdinout),
    WriteString(stdinout, '                                   Program
Dataread', 0),
    WriteLn(stdinout);
    WriteLn(stdinout),
    WriteLn(stdinout);
    WriteLn(stdinout),
    WriteString(stdinout, '                 R  Read data from hard
disk and write a temp profile', 0),
    WriteLn(stdinout),
    WriteLn(stdinout),
    WriteLn(stdinout),
    WriteString(stdinout, '                 Q  Quit and return to
DOS', 0),                              WriteLn(stdinout);
    WriteLn(stdinout),
    WriteLn(stdinout),
    WriteLn(stdinout);
    WriteString(stdinout, '                             Enter your
selection [R or Q]    ', 0),
    ReadBuffer(on),
    ReadChar(stdinout, achr),
    ReadLn(stdinout),
    ReadBuffer(off),
    WriteLn(stdinout),
    WriteLn(stdinout),
    CASE achr OF
'r', 'R'            ReadDataAndZeroSumIt,         :
'q', 'Q',
'x'  'X'            Terminate(normal),
    ELSE    ,
```

```
    END, (*case*)
    WriteLn(stdinout),
UNTIL FALSE,
END DATAREAD
```



```
( $C-)

PROGRAM MarkGood,

   VAR
     done                                          : boolean;
     achr                                            char,
     i,
     j,
     disk_block                                    : integer,
     result                                          record
                                                     ax,
                                                     bx,
                                                     cx,
                                                     dx,
                                                     bp,
                                                     si,
                                                     di,
                                                     ds,
                                                     es,
                                                     flags : integer,
                                                     end,

     data_record      record
                      data      array [0      255] of integer,
                      end,


procedure read_disk;
begin
with result do
  begin
    cx  = 1,
    dx  = disk_block,
    ds  = seg(data_record),
    bx  = ofs(data_record),
    ax  = 2,  (read)
    intr ( $4f, result),
    (writeLn('read ',disk_Block),)
  end,
end,
```

```
procedure write_disk;
begin
with result do
     begin
     cx := 1;
     dx := disk_block;
     ds := seg(data_record);
     bx := ofs(data_record);
     ax := 3;  {write}
     end;

{writeln('write disk block = ',disk_Block);}
intr ( $4f, result);
end;

BEGIN {mainline}
repeat
writeln;
writeln;
writeln('Mark good those hard disk bad blocks from markbad');
writeln;
writeln;
writeln('1 Examine FAT for bad blocks in data area');
writeln;
writeln('2 Mark last 1/3 of hard disk good');
writeln;
writeln('3 Examine manually a sector');
writeln;
writeln('4 Exit');
Writeln;
write  ('                                              Enter your
selection =  ');

achr := ' ';
readln(achr);
case achr of
'1'  begin
      j := 0;
      for Disk_block := 40 to 64 do
        begin
        Read_Disk;
        for i := 0 to 255 do
          if j <= 10
          then
            begin
            if data_record.data[i] = 0
              then {all is ok}
              else
                begin
                writeLn('Possible bad disk area or data in
```

```
reserved area s:i:d ',
                                Disk_Block:6,
                                i:6,
                                data_Record.data[i]:6);
                    j := j + 1;
                    if j > 10 { too many errors?}
                      then
                        begin
                        write('Continue display? Y/N =  ');
                        readln(achr);
                        if achr in ['y','Y'] then j := 0;
                        end;
                    end;
                end;
            end;
        end;

'2'     begin
        for Disk_block := 40 to 64 do
          begin
          Read_Disk;
          for i := 0 to 255 do data_record.data[i] := $0000;
          Write_disk;
          end;
        end;

'3'     begin
        write('Sector to read = ');
        readln(Disk_block);
        Read_disk;
        for i := 0 to 255 do
          begin
            write (data_record.data[i]:4);
            if (i mod 16) = 15 then writeln;
          end;
        end;

else ;

    end; {case}
until Achr = '4';
END.
```

```
{ $C-}

PROGRAM MarkBad;

   VAR
     done                                          : boolean,
     achr                                            char;
     i,
     j,
     disk_block                                    : integer;
     result                                          record
                                                     ax,
                                                     bx,
                                                     cx,
                                                     dx,
                                                     bp,
                                                     si,
                                                     di,
                                                     ds,
                                                     es,
                                                     flags   integer;
                                                    end;

     data_record    record
                    data     array [0 .. 255] of integer;
                    end;

procedure read_disk,
begin
with result do
  begin
    cx  = 1,
    dx  = disk_block,
    ds  = seg(data_record),
    bx  = ofs(data_record),
    ax  = 2;  {read}
    intr ( $4f, result),
    {writeLn('read ',disk_Block);}
  end,
end,


procedure write_disk,
begin
with result do
    begin
    cx  = 1,
    dx  = disk_block,
```

```
     ds  := seg(data_record);
     bx  := ofs(data_record);
     ax  := 3,  {write}
     end;

{writeln('write disk block = ',disk_Block);}
intr ( $4f, result),
end,

BEGIN {mainline}
repeat
writeln;
writeln;
writeln('Mark hard disk bad blocks');
writeln;
writeln;
writeln('1 Examine FAT for bad blocks in data area');
writeln;
writeln('2 Mark last 1/3 of hard disk bad');
writeln;
writeln('3 Examine manually a sector');
writeln,
writeln('4 Exit');
Writeln,
write  ('                                                  Enter your
selection"=  '),

achr := ' ';
readln(achr),
case achr of
'1'  begin
     j := 0,
     for Disk_block :=  40 to 64 do
       begin
       Read_Disk,
       for i := 0 to 255 do
         if j <= 10
         then
           begin
           if data_record data[i] = 0
             then {all is ok}
             else
              begin
              writeLn('Possible bad disk area or data in
reserved area s i d ',
                             Disk_Block:6,
                             i 6,
                             data_Record data[i] 6);
             j  = j + 1;
             if j > 10 { too many errors?}
               then
                 begin
```

```
                    write('Continue display? Y/N =   '),
                    readln(achr),
                    if achr in ['y','Y'] then j := 0;
                    end,
                end,
            end,
          end;
        end;

'2'     begin
        for Disk_block := 40 to 64 do
          begin
          Read_Disk,
          for i := 0 to 255 do data_record.data[i] := $fff7;
          Write_disk,
          end;
        end;

'3'     begin
        write('Sector to read = '),
        readln(Disk_block),
        Read_disk;
        for i := 0 to 255 do
          begin
            write (data_record.data[i]:4),
            if (i mod 16) = 15 then writeln,
          end;
        end,

else ,

      end; {case}
until Achr = '4';
END.
```

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